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Production harmonizEd Reconfiguration of Flexible Robots and Machinery

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Deliverable 2.1

Guidelines for seamless integration of Humans as flexibility driver in flexible production systems

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Abstract - Executive summary

Human can be integrated in Cyber Physical Systems according to two main models: as Human-in-the-Loop or as Human-in-the-Mesh. Each of the two models corresponds to a different set of activities that influences the performances of the production systems.

Humans can supervise and adjust the settings, be a source of information or of disturbance, can diagnose situations, make decisions and several other activities influencing manufacturing performances, overall providing degrees of freedom and flexibility to the systems. Humans affect the behaviour of manufacturing systems both in a positive and in a negative manner.

Challenges and opportunities for turning human behaviour into a valuable effect rather than into a nuisance emerge in the transformation from AS IS manufacturing systems to TO BE Cyber Physical Production Systems.

In particular, the analysis of barriers and enablers has led to the identification of a set of recommendations for Human-in-the-Loop and Human-in-the-Mesh scenarios, encompassing organizational aspects, methods and technologies.

These findings can provide a preliminary insight to the integration of humans as flexibility drivers in future PERFoRM enhanced flexible manufacturing system. Further investigations are planned to provide additional elements to validate, disconfirm or extend the proposed analysis framework and recommendations.

The results of the second iteration of this study will be issued in one year from now, corresponding to the mid of the PERFoRM project duration.

1 Table of Contents

1. INTRODUCTION **7**

1.1. Objectives and scope 7
1.2. Integration within the project activities 7
1.3. Structure of the document 7

2. METHODOLOGICAL APPROACH **8**

3. PRODUCTION SYSTEMS CHARACTERIZATION **9**

3.1. Production systems, phases and states 9
3.2. Production activities and roles 11
3.1.1 Production activities and roles *11*
3.1.2 Maintenance Management & Scheduling *15*
3.3. Socio-Technical Systems and Lean Production Systems 18
3.4. Flexibility performances in production 19
3.5. Social/human performances in production 20

4 ORGANIZATIONAL FRAMEWORK AND ANALYSIS OF REQUIREMENTS, CHALLENGES AND OPPORTUNITIES FOR EACH USE CASE **21**

4.1 I-FEVS 21
4.1.1 Production System *21*
4.1.2 "AS IS" *22*
4.1.3 "TO BE" *23*
4.1.4 Highlights *25*
4.2 GKN 25
4.2.1 Production system *25*
4.2.2 "AS IS" *26*
4.2.3 "TO BE" *26*
4.2.4 Highlights *27*
4.3 SIEMENS 28
4.3.1 Production system *28*
4.3.2 "AS IS" *30*
4.3.3 "TO BE" *31*
4.3.4 Highlights *34*
4.4 WHIRLPOOL (WHIRLPOOL) 35
4.4.1 Production system *35*
4.4.2 "AS IS" *35*
4.4.3 "TO BE" *35*
4.4.4 Highlights *36*

5 GAP ANALYSIS AND RECOMMENDATIONS **36**

5.1 Gap analysis 36
5.2 Recommendations 40
5.2.1 Human-in-the-Loop Recommendations *41*
5.2.2 Human-in-the-Mesh Recommendations *42*

6 CONCLUSIONS AND OUTLOOK 42

I. APPENEDIX – SOCIAL PERFORMANCE INDICATORS 44

II. APPENDIX – QUESTIONNAIRES GATHERED FROM THE USE CASES 50

A. I-FEVS 51
B. GKN 68
C. SIEMENS 95
D. WHIRLPOOL 113

III. APPENDIX - ANALYSIS OF SELECTED SCENARIOS WITHIN THE USE CASES 129

A. I-FEVS 130
B. GKN 134
C. SIEMENS 138
D. WHIRLPOOL 147

2 List of Figures

Figure 1 Methodological Approach 8
Figure 2 - Classification of Manufacturing Systems 9
Figure 3 - Manufacturing System Lifecycle Phases and Production States 10
Figure 4 - Significance of social issues for industries (source MIT Sloan 2013) 20
Figure 5: Duisburg plant overview 29
Figure 6: Shop floor Layout 30
Figure 7: simplified Flow Chart for Disturbance reaction 34
Figure 8 - Types of scenarios with reference to the Architectural view 37
Figure 9 - Types of scenarios with reference to the ISA 95 standard 37
Figure 10 Human-in-the-Loop: human activities 38
Figure 11 Selected scenarios coverage of the Lifecycle phases and Production states 40

3 List of Tables

Table 1: Interactions between the ISA-95 production operation activities, input is referring to the activity that is initiating the interaction, output is referring to the receiving activity 14

1. Introduction

1.1. Objectives and scope

This deliverable will report the results of the analysis of the impact and influence of the human integration as a flexibility driver in the production systems.
The objectives include the identification of the needs and roles of humans in production systems to achieve flexibility and adaptation and the formulation of guidelines and recommendations for a seamless collaboration between human, robots and machinery.
The scope of this study encompasses the four Use Cases considered in the PERFoRM project, as a basis to be extended to Cyber-Physical-Production-Systems.

1.2. Integration within the project activities

The activities to develop the present guidelines belongs to T2.1 and have been undertaken in parallel with the collection and analysis of the requirements for Innovative flexible and reconfigurable Production System and KPI identification (T1.2) and of the requirements for technologies, tools to be adopted and tested.
The results from this task will further act as a basis for T.3.3 and T4.3, where the requirements for human observations and monitoring and visualization of KPIs will be elicited. Results will be eventually validated in WPs 7, 8, 9 and 10.

1.3. Structure of the document

The structure of the document, after this introduction, include:

the methodological approach proposed to achieve the objectives of this task;

the reference to the state of the art necessary to characterize manufacturing systems, their relevant performances, the role, the organization and decision making processes of humans in this context;

the study of the four use cases, performed in accordance with the above mentioned methodological framework, highlighting the challenges and opportunities emerging with adoption of the project solutions;

the analysis of the gaps between the AS IS organizations and the needs for the TO BE situation, implied by the challenges and opportunities of the TO BE situation;

the recommendations preliminary identified as valuable to bring the AS IS organization to capture the opportunities and address the challenges of the TO BE;

the conclusions to the present document, highlighting the achieved results and their limitations, including an outlook to future activities.

2. Methodological Approach

Figure 1 Methodological Approach illustrates the pathway proposed to pursue the seamless integration of humans as flexibility drivers in CPPS.

First of all, the identification of the target system is proposed, through the definition of the scope, boundaries, the manufactured products and parts, the involved human resources and the equipment.

As a second step, an analysis of the AS IS situation, including the characterization of the organizational context and the relevant performances, allow the identification of the objectives and constraints of production system.

Then, the TO BE situation is envisioned and developed considering different scenarios, corresponding to different phase of the lifecycle and different possible states of the production system in order to preliminary identify challenges and opportunities with reference to the roles of humans.

A gap analysis between the AS IS situation with its objectives and constraints and the TO BE scenarios with all the associated issues represents the critical step. The gap analysis leads to the identification of possible solutions, and to the elaboration of guidelines and recommendations to exploit the opportunities and address the challenges, by overcoming the existing barriers and exploiting available enablers..

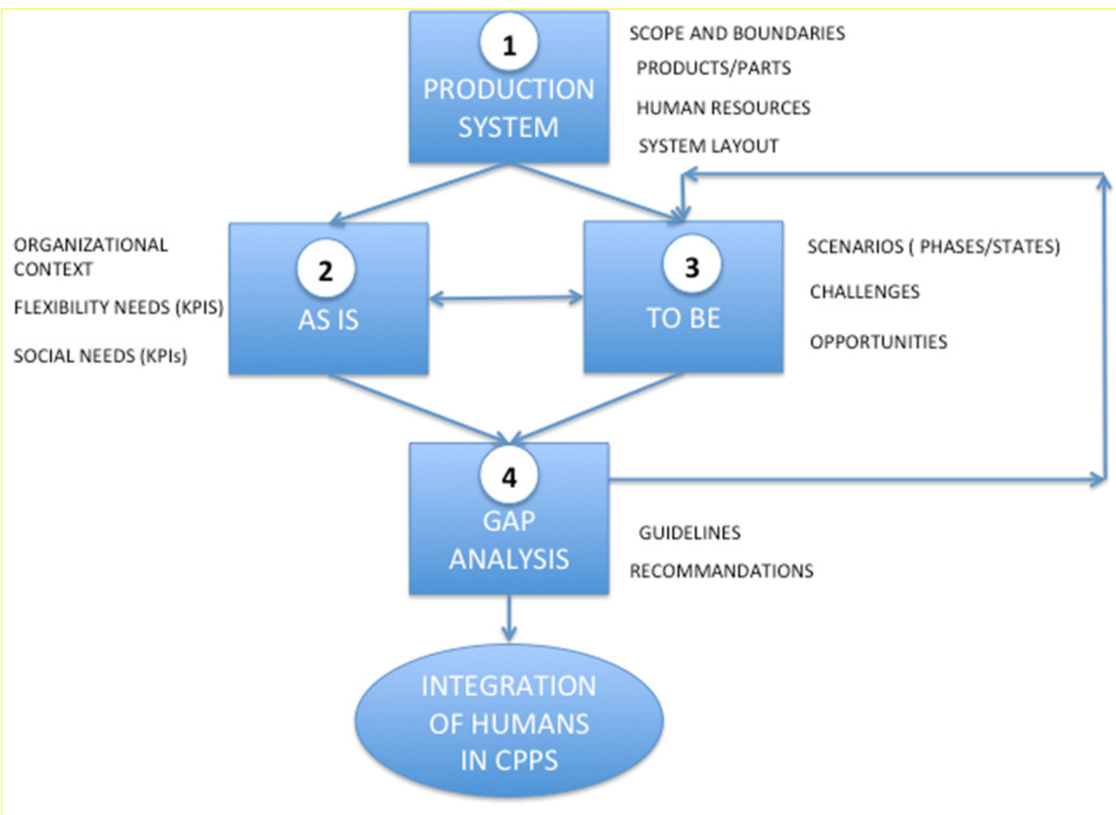


Figure 1 Methodological Approach

3. Production systems characterization

3.1. Production systems, phases and states

Production systems

The notion of production systems is grounded on the concept of system:: "A system is a construct or collection of different elements that together produce results no to obtainable by the elements alone. The elements, or parts, can include people, hardware, software, facilities, policies, and documents; that is, all things required to produce systems-level results. The results include system level qualities, properties, characteristics, functions, behavior and performance. The value added by the system as a whole, beyond that contributed independently by the parts, is primarily created by the relationship among the parts; that is, how they are interconnected." (Haskins & Forsberg, 2007)

Production System are specific systems, which aim is devoted to making products.

Classification of production systems

Production systems can be classified along the following main dimensions:

- Process nature: part production/process production
- Production management: batch production/flow production
- Market: make-to-order/ make-to-stock

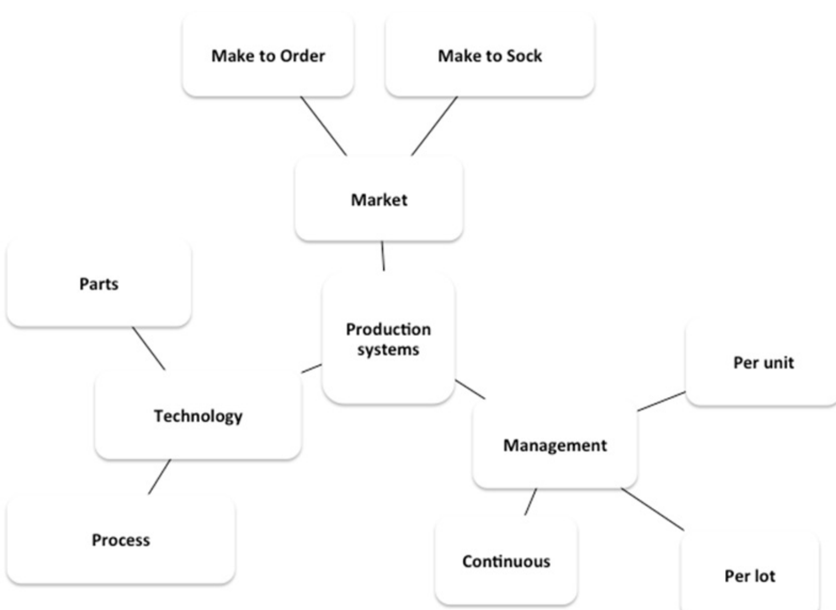


Figure 2 - Classification of Manufacturing Systems

Production systems' lifecycle phases

Production systems exert their function when there are in operation but, for the purpose of this document, it is important to take into account their lifecycle.

The main phases, illustrated by the higher arrow in Figure 3 - Manufacturing System Lifecycle Phases and Production States, and adapted from (Pedrazzoli, et al., 2007), are:

- **Planning & Engineering** This phase comprehends the concepts, design, feasibility analysis of new production system.
- **Building and adaptation (reconfiguration)** This phase comprehends bot the initial building of the production systems and the following adaptations/reconfigurations. This phase is particularly relevant in the context of PERFoRM, as the solutions developed in the project aim at allowing frequent and seamless reconfigurations of the system "plug and produce". Besides recurrent reconfigurations "by-design", further adaptations may be needed during the system lifecycle to face unexpected changes deriving from the customers, the technology, the norms, the purchased parts, etc.).
- **Ramp-up** – This phase bringing the system to the full production rate by optimzing the system components and the process parameters.
- **Production** – This is the core activity of the production systems and will be further analysed in the following sections. (Basse, Sauer, & Schmitt, 2014).
- **Refurbishment/Dismantling** – This is end of life of the manufacturing system that may lead, through a thorough transformation, to a new factory/line or to its demolition.

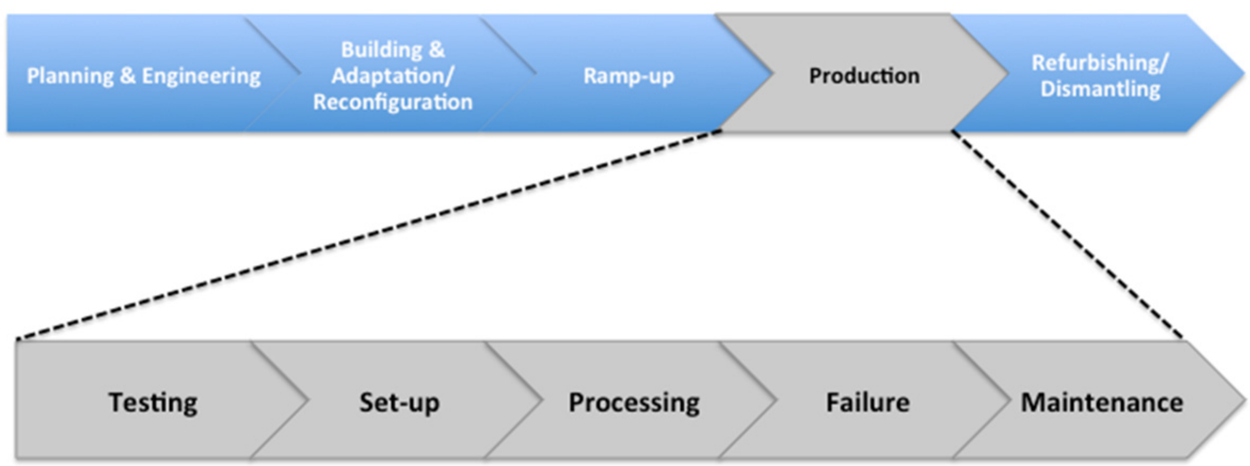


Figure 3 - Manufacturing System Lifecycle Phases and Production States

Production states

The production phase is the core activity and is aimed at making. However, the production system is not continuously productive during the production phase. As well analysed in the studies to determine the

OEE of the plants (Grando & Turco, 2005), a production system may be non-productive states due to external or internal causes.

During the production phase of the lifecycle, as illustrate by the vertical arrow in Figure 3 - Manufacturing System Lifecycle Phases and Production States, the following type states have been considered, as relevant for the purpose of the PERFoRM project:

- Testing
- Set-up
- Processing
- Failure
- Maintenance

The system states are relevant for analysing the role of humans in productions systems, as the activities of the teams and individual depend on them. In fact, when the production system is under maintenance, usually the maintenance team are operating on the plant while the production operators are involved in other activities than operating the plant.

3.2. Production activities and roles

3.1.1 Production activities and roles

In Section 3.1, some main notions concerning production systems have been recalled. In the present section, some relevant concepts concerning production activities and organization are summarized.

Generalized production activities are defined in the norm ANSI/ISA 95.00.03, the stated model is called *Production operations management activity model*. The defined activities are not related to software, personnel or systems. The model is supposed to include what is done in production operations and not how production operations should be organized, as different institutions may have different structures and therefore a different allocation of personnel, software and systems to roles. The production activities are located on Level 3 of the multi-level architecture proposed in ISA-95 (see Figure 1).

- Level 0 represents the actual production process and is not further described.
- Level 1 is sensing and manipulating the production process.
- Level 2 is including monitoring activities of the production process.
- Level 3 is including the work flow to produce end products, maintaining records and process optimization (MES, LIMS, etc.)
- Level 4 is including a basic plant schedule, material use, delivery, shipping and inventory. (ERP)

Therefore, the production activities influence/are influenced (by) the lower Levels 2, 1, 0 and the higher Level 4.

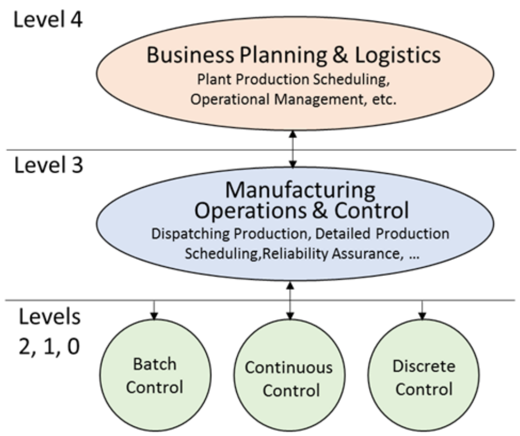


Figure 1: Multi-level reference for the identification of the relevant functions in the enterprise and in the domains of manufacturing and control (ANSI/ISA 95.00.01)

The detailed, generalized activities of the *Manufacturing Operations & Control Level* are shown in Figure 2. When looking at the human as driver, the human might not be found in the execution of every activity. Some activities tend to be automated more often than others due to their characteristics (e.g. production data collection is automated in state-of-the-art production systems, but can also be found manual variants in legacy production processes). Each activity has connections to other activities and/or to higher or lower level functions. To sum up the interactions, Table 1 gives an overview, describing the interactions between all activities. Whereas higher level functions are referred as *Business Planning & Logistics,* the lower level function are referred as *Process Control*.

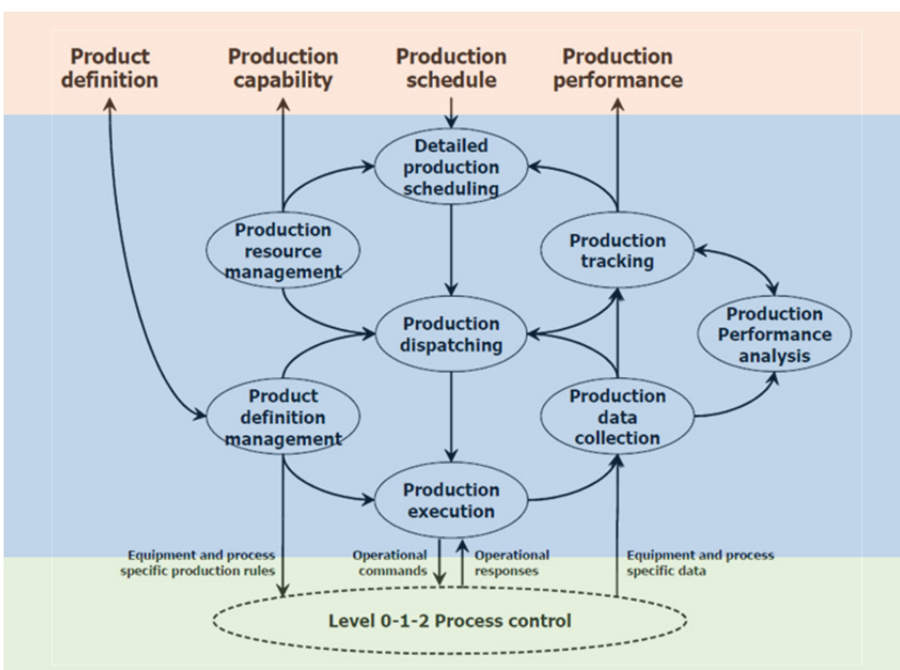


Figure 2: Activity model of production operations management

The **product definition management** is referring to activities that include product production rules and all information of the area or site. Tasks in this activity include among others: The managing of documents (e.g. product variant definitions or manufacturing instructions), maintaining the detailed production routing of each product and maintaining the Key Performance Indicators associated with production.

The **product resource management** refers to activities that mange information about necessary resources for production (e.g. tool, machines, labor, materials, energy). Tasks in this activity include, among others: Managing of reservations for future use of resources, collecting of information regarding the current state of personnel, equipment and material and ensuring resources are available for the assigned task.

The **detailed production scheduling** takes the enterprise level production schedule and determines the best use of local recourses to meet schedule requirement. Tasks in this activity are among others, the comparing actual production to planned production and the creation and maintaining of the detailed production schedule.

The **production dispatching** refers to a collection of activities organizing the production flow with dispatching production to personnel and equipment, this activity directly connects to the *detailed production scheduling*. This includes among other the scheduling of batches in a batch control system and the sending of work orders to work cells. As main parts the *assignment of work* and *dispatch lists* can be regarded.

The **production execution** is a collection of activities that direct the content of the dispatch list elements. It is responsible for selecting, starting and moving units to work. Tasks of this activity are among other directing the performance of work and informing other activities in case of unexpected events in the inability to meet the work requirement.

The **production data collection** is retrieving, collecting and achieving data from different sources. The possible data ranges from process information, associated properties to sensor and actuator statuses. Tasks are among others: Providing standardized on-demand reports and providing product quality information.

The **production tracking** is reporting summarizing actually consumed resources and produced products. Tasks of the production tracking activity are among other: Providing information for genealogy analysis and recoding material flow in detail.

The **production performance analysis** gives back feedback to the higher level about production. This feedback is based on analyzed information. Examples for tasks are performance/cost reports, comparison of different production lines or evaluating constraints to capacity and quality.

Table 1: Interactions between the ISA-95 production operation activities, input is referring to the activity that is initiating the interaction, output is referring to the receiving activity

Activities: input → output ↓	Product definition management	Production resource management	Production scheduling (detailed)	Production dispatching	Production execution	Production data collection	Production tracking	Production performance analysis	Process control	Business management & Controlling
Product definition management			Work center specific product production rules and detailed production routing	Work center specific product production rules and detailed production routing	Work center specific product production rules and detailed production routing			Production KPI definitions	Work center specific product production rules	Into product definition
Production resource management			Resource availability	Resource availability				Resource availability		Into production capability
Production scheduling (detailed)		Detailed production schedule								
Production dispatching					Dispatch list		Dispatch list relating work to resources			
Production execution						Production information and events			Operational commands	
Production data collection							Resource history data	Operating data, equipment status, resource usage		
Production tracking			Reports on WIP and work completed					Quality and performance data		Into production performance
Production performance analysis							Quality and performance data			
Process control		Current information			Operational responses	Resource & operations data, equipment status & configuration, alarms, operator actions & comments				
Business management & Controlling	Product definition		Production schedule, Product definitions							

When looking at human actions or roles regarding the activities no general allocation can be done due to the variety of divergent executed production systems, as described earlier. Subsequently possible roles can be identified with the help of the *Production operations management activity model,* when applying the model to a specified case.

3.1.2 Maintenance Management & Scheduling

Over the recent decades the automation level of production has increased and the number of production personnel has declined. Therefore, the need for maintenance of high invest production/automation technology rises. This results in more research activities in the field of maintenance management. The definition of maintenance can be stated as the combination of all linked administrative and technical actions aimed to retain an item or system – or restore it to a state it performs as intended (British Standards Institution, BS3811).

The field of maintenance is relatively broad and can be divided in different areas, a literature review of (Garg & Deshmukh, 2006) is differentiating between maintenance optimization models; techniques; scheduling; performance measurement; information systems and policies (Garg & Deshmukh, 2006). Whereas *maintenance optimization models* intend to find out the best balance between benefits and costs of maintenance actions (Dekker, 1996). E.g. a subjective Bayesian approach can be concerned with presenting uncertainties regarding future events in context of inspection maintenance for decision makers (Apeland & Scarf, 2003). *Maintenance techniques* are defining how maintenance is conducted. E.g. one subdivision is predictive maintenance (PM), PM tries to read signs that indicate an approaching failure (Hashemian & Bean). The category *scheduling of maintenance* includes approaches to combine the six elements of successful maintenance (mechanic(s), materials/parts, availability of units to be serviced, information needed, necessary permissions). Different techniques, like PM can be used to schedule maintenance activities. *Maintenance performance measurement* is interpreting maintenance data and state predefined performance indicators. One example is the Balanced scorecard, used to report performance measurement to the management. *Maintenance information technology* is a relatively new domain, integrating maintenance management in higher hierarchy systems. E.g. (Pintelon, Du Preez, & Van Puyvelde, 1999) state the opportunities generated by IT systems for maintenance. The final area identified in literature are the *maintenance policies*, this area is concerned how maintenance activities of deteriorating systems are carried out. The policies can vary; some examples are: Age replacement policies or failure limit policies (Wang). An overview of the presented maintenance management area according to (Garg & Deshmukh, 2006) is stated in Figure 3.

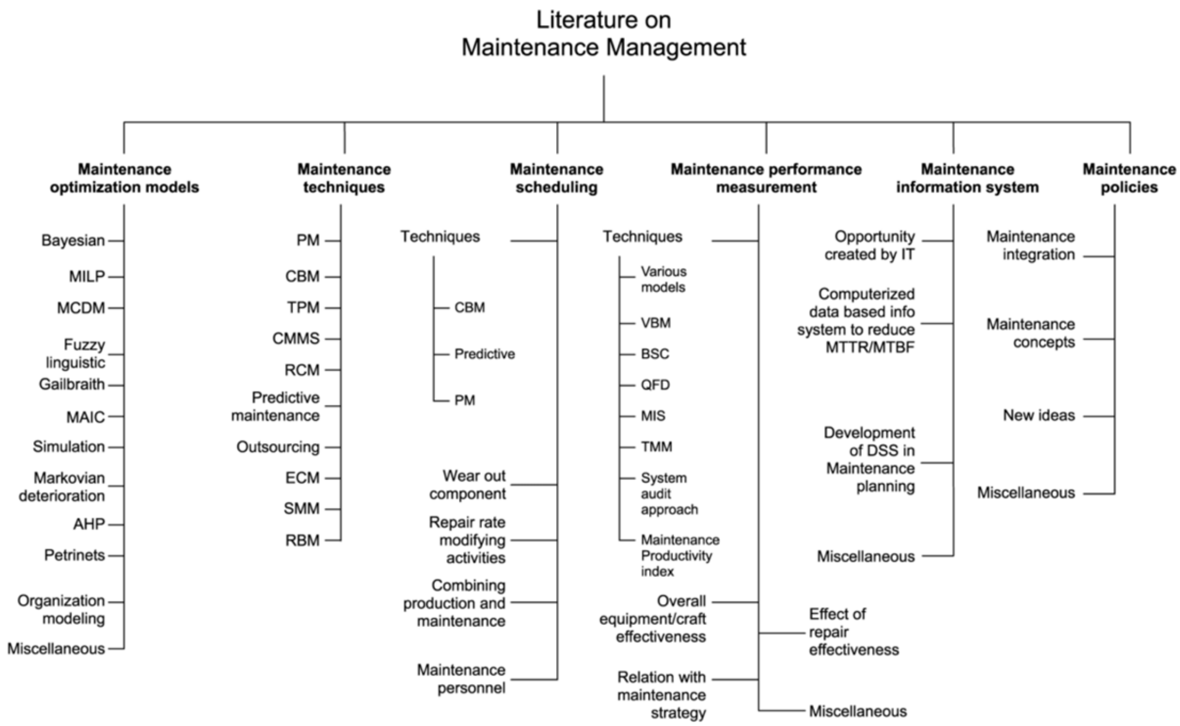


Figure 3: Overview: Maintenance Management in the literature, categories and sub-categories (Garg and Deshmukh, 2006).

Following the area of maintenance scheduling techniques will be explained. Different categories/techniques for maintenance scheduling can be extracted from literature, and will be stated in the paragraphs below.

Corrective maintenance

Corrective Maintenance (CM) is performed to diagnose, isolate, and fix a failure to restore the optimal operational condition of a machine again, this happens within the tolerances or limits established for in-service operations. CM is carried out after a failure occurs. It also includes the identification of causes for reoccurring breakdowns and low performance as consequence of design malfunction. (Duffuaa, Raouf, & Campbell, 2015).

Preventive maintenance

Preventive Maintenance (PM), "[…] is defined as a series of preplanned tasks performed to counteract known causes of potential failures of the intended functions of an asset. It can be planned and scheduled based on time, use, or equipment condition." (Duffuaa, Raouf, & Campbell, 2015). PM is preferred to CM, due following reasons:

- Failures can be reduced by proper cleaning, adjustments, inspection and lubrication set off by performance measurement.
- When a failure can't be prevented, regular measurements and inspections support the reduction of the degree of failure and possible subsequent causes on other components.

- A warning of impending failure may be detected when monitoring progressive degradation of a function parameter (e.g. machine vibration or product quality).
- Unplanned interruption is damaging to the production output in the most cases. Thus planned, preventive maintenance can negotiate this potential loss, compared to CM.

The central question of PM is to define what tasks should be performed to prevent failure. This is dependent on the failure mechanism and therefore on the manufacturing step that is addressed. (Duffuaa, Raouf, & Campbell, 2015).

Condition based maintenance

Condition Based Maintenance (CBM) is subcategory of PM. CBM is defined as maintenance when need arises and therefore relying on equipment performance and condition monitoring. Maintenance is carried out when a defined number of indicators show that equipment tends to fail. The objective of CBM is that equipment, machines or systems are operating in the most cost-efficient way. (Ellis, 2008)

Predictive maintenance

Predictive Maintenance (PdM) is defined as follows: “A comprehensive predictive maintenance management program uses the most cost- effective tools (e.g., vibration monitoring, thermography, tribology) to obtain the actual operating condition of critical plant systems and based on this actual data schedules all maintenance activities on an as-needed basis.” (Mobley, 2001). Thereby PdM techniques are used, which help to determine the condition of operating equipment and predict when maintenance should be performed. When comparing to PM or regular scheduled maintenance this approach results in cost savings, as maintenance is only performed when justified. The difference to CBM is the prediction component which is e.g. resulting from a combination of sensoring and simulation.

(Hashemian & Bean) discuss the state-of-the-art of maintenance techniques in their paper and come to the conclusion that plants should move from time-based maintenance and CM towards the advanced predictive maintenance, especially with the latest sensor technology (Hashemian & Bean).

Processes, tasks, roles and decision-making

The human activities related with the transformation processes are ruled within the operation management through the activities of organizing, planning, and controlling.

Organizing consists in defining a structure of roles with the dependencies, relationships, and flow of information.

Planning activities define the future course of action and steer decision-making.

Controlling activities ensure the actual behaviour and performances correspond with the plans.

The activities of individual humans operating in a manufacturing system can be described in terms of roles. Each role corresponds to certain goals, to the tasks that are necessary to achieve these goals, to the responsibilities and authorities that are associated to performing those activities and the involved decision-making.

3.3. Socio-Technical Systems and Lean Production Systems

The scientific approach to work organization in production systems, generally referred to as Fordism-Taylorism, has dominated the discipline until the research actions carried out by the Tavistock Institute, brought a different perspective in organizational design: a way to achieve performances alternative to increasing bureaucratization was identified, characterized by group cohesion, self-organization, participation of the workers to decision making (Trist, 1981).

The studies on worker motivation provided useful insight for the design of jobs and of work organization (i.e. hygiene and motivator factors, principles for enriching jobs and increase the motivation of workers (Herzberg, 1985)).

Socio-technical thinking has become a major trend influencing many firms all over the world (Niepce & Molleman, 1998). However, since its emergence in 1988, the Lean Production System has become a competing and soon a dominant approach (Dabhilkar & Ahlstrom, 2013).

Originated on the basis of the Japanese Toyota Production System, revisited and disseminated in the Western countries as the Lean Production System by the researchers of MIT, this approach is both a global philosophy and a set of concepts and practices (Turesky & Connell, 2010).

The STS approach, originated as a way to overcome the pure technological constraints and encompass social requirements to find the best match that ensures economic as well as human results (Trist, 1981). The LPS concept originated in Japan after the end of the second world war to overcome financial restrictions and improve quality for the customer with less resources, by eliminating wastes and unnecessary consumptions (Bhamu & Sangwan, 2014).

Although in the majority of the Lean Manufacturing definitions collected in (Bhamu & Sangwan, 2014) highlight the reduction of waste, the focus on value, some definitions stress the central role of the persons, as thinkers and promoters of continuous improvement.

In the last decades, several researchers and practitioners have studied, analyzed and compared the two approaches; investigated about barriers, enablers to the adoption; collected practices and formulated frameworks and guidelines for the implementation. Others have debated whether LPS and STS were alternative or converging models, and companies developed their own XPS by selecting and blending elements of the two paradigms, depending on different aspects.

Some typical features that allow characterizing a production system as closer to STS or to LPS are the following:

- Teamwork – A very relevant feature for STS, is also important for LPS

- Skill variety – The enlargement of jobs and related requirements for skill variety is typically pursued in STS, but skill variety is also valuable for LPS
- Task identity – STS aim at he correspondence of a task to a whole unit of work, as the visible contribution to the final product, which is not the case in LPS.
- Cycle time – Longer cycles time are associated with STS, while usually shorter cycles time are associated with LPS.
- Level of standardization – LPS attribute great value to standardization, while STS tend to leave the workers more autonomy on how to execute the tasks.
- Feedback – especially for STS it is of the utmost importance that the workers receive feedback from the process concerning the output of their task.
- Workers participation to continuous improvement – LPS highly value the participation of workers to continuous improvement initiatives.

3.4. Flexibility performances in production

In order to analyse the possible contribution of humans as flexibility drivers, a common interpretation of production flexibility is necessary. The concept of flexibility is poorly understood (SHEWCHUK & MOODIE, 1998) and requires some clarification.

First of all, there are different types of flexibility depending on the considered dimension (D'Souza & Williams, 2000):

- volume,
- variety,
- process,
- material handling,
- labour
  etc.

In addition, any flexibility dimension is characterized by four elements (Koste, Malhotra, & Sharma, 2004):

- range-number, represents the width of the difference between two options
- range-heterogeneity, represents the degree of differences between two options
- mobility, represents the ease to move from one option to the other
- uniformity measures any deterioration of the performances of the system to use flexibility
  etc.

For the purpose of analysing the flexibility requirements within PERFoRM, a framework has been proposed, grounded on the above-mentioned references to the literature, based on the dimension, and the four elements.

3.5. Social/human performances in production

Increasing attention in the last decades has been devoted to social issues at the enterprise level, where standards on social responsibility and social sustainability are becoming more and more widespread, such as ISO 26000 and Global Reporting Initiative GRI G4.

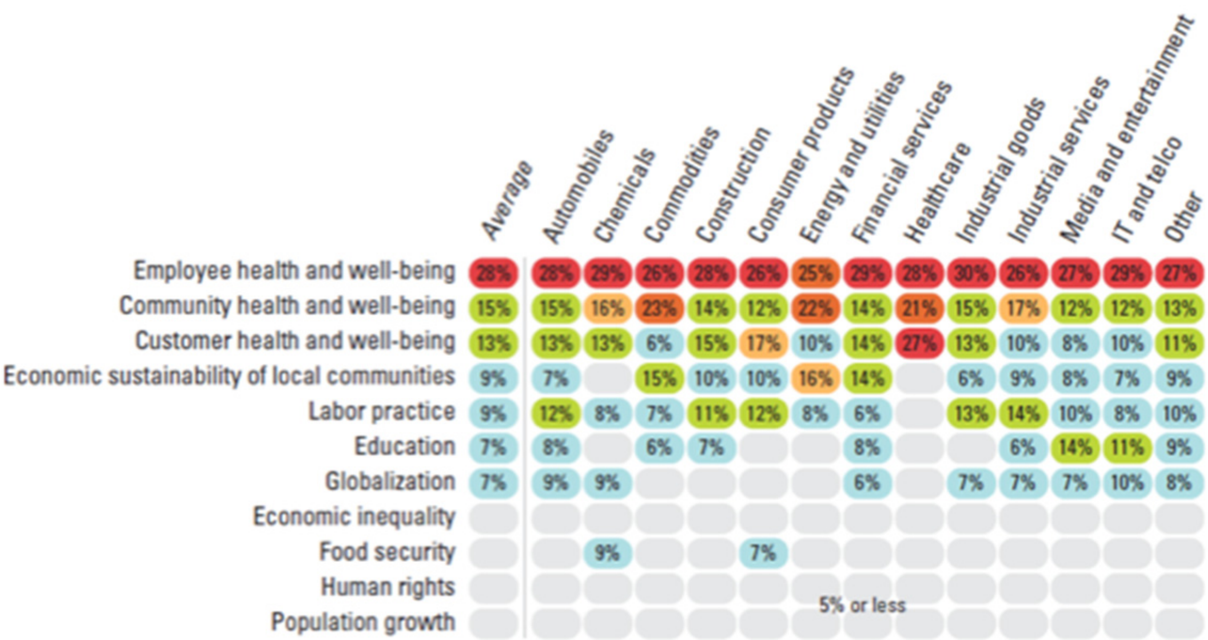
The main themes relevant for human issues include:

Labour: Employment, labour/management relations, occupational health and safety, training and education, diversity and equal opportunity, equal remunerations for women and men, supplier assessment for labour practices, labour practices grievance mechanisms

Human Rights: Investments, freedom of association and collective bargaining, child labour, forced or compulsory labour, security practices, indigenous rights, assessment, supplier human rights assessment, human rights grievance mechanisms

Social: Anti-corruption, public policy, anti-competitive behaviour, compliance, supplier assessment for impacts on society, Individual career, worker wellbeing

The significance of the individual social issues depend on the industrial sector (MIT Sloan, 2013), as illustrated in Figure 4 - Significance of social issues for industries.



	Average	Automobiles	Chemicals	Commodities	Construction	Consumer products	Energy and utilities	Financial services	Healthcare	Industrial goods	Industrial services	Media and entertainment	IT and telco	Other
Employee health and well-being	28%	28%	29%	26%	28%	26%	25%	29%	28%	30%	26%	27%	29%	27%
Community health and well-being	15%	15%	16%	23%	14%	12%	22%	14%	21%	15%	17%	12%	12%	13%
Customer health and well-being	13%	13%	13%	6%	15%	17%	10%	14%	27%	13%	10%	8%	10%	11%
Economic sustainability of local communities	9%	7%		15%	10%	10%	16%	14%		6%	9%	8%	7%	9%
Labor practice	9%	12%	8%	7%	11%	12%	8%	6%		13%	14%	10%	8%	10%
Education	7%	8%		6%	7%			8%			6%	14%	11%	9%
Globalization	7%	9%	9%					6%		7%	7%	7%	10%	8%
Economic inequality														
Food security			9%			7%								
Human rights														
Population growth														

Figure 4 - Significance of social issues for industries (source MIT Sloan 2013)

In the scope of the PERFoRM project, the main emphasis is on employees.

There is a wealth of relevant aspects to be considered with references to employees, such as health and safety, on their wellbeing and commitment, but also on their knowledge, skills, personal growth, etc.

Therefore it is important to specify the objectives and expected performances in a clear and measurable manner, through the use of PI (performance indicators).

In I **APPENEDIX – Social Performance Indicators**, a list of these indicators, taken form the result of the SO SMART project (SO SMART project), is provided as a reference.

4 Organizational framework and analysis of requirements, challenges and opportunities for each Use Case

This section is grounded on the content of the questionnaires completed by the Use Case partners and reported in II **APPENDIX – Questionnaires gathered from the Use Cases**.

In particular, for each Use Case, the information gathered corresponds to the steps 1-3 of the methodological approach of Figure 1 Methodological Approach, concerning:

- the identification and characterization of the portion of the production system subject to the demonstration of the PERFoRM solutions, as a use case;
- the description of organizational context and of the flexibility and social needs in the AS IS situation;
- the recognition of challenges and opportunities to leverage the human role in the TO BE situation.

4.1 I-FEVS

4.1.1 Production System

The system subject to be the Use Case for developing and demonstrating PERFoRM is located in the Rivoli Plant and consists of the “Micro electric vehicles” line.

The line assembles micro-electric vehicles. The main parts are:

- tubular chassis for passenger vehicle
- tubular chassis for delivery of goods
- axle frame

The Use Case will involve directly 12 people

- 1 Supervisor
- 10 operators (3 types of specialization: welding, robotics, software engineering)
- 1 quality engineer

and indirectly 2 people

- 1 maintenance technician
- 1 product engineer

4.1.2 "AS IS"

The organizational context seems to blend features typical of socio-technical systems with high task identity and feedback from the process with typical characteristic of the lean principles typical of the automotive industry, such as a high level of standardization and the participation of the workers to continuous improvement initiatives.

The needs for flexibility concern different dimensions:

Volume: 5-50 vehicles/day

Variety: 2 different architectures of the chassis (figure 3):

Process: requested flexibility

The production line has to be built in order to easily switch from one configuration to another one.

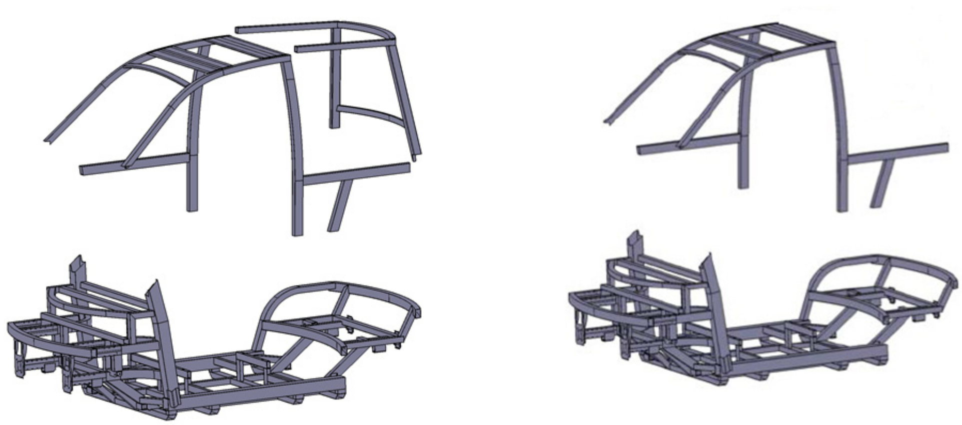


Figure 3: Chassis in the passenger configuration (left) and chassis in the cargo configuration for the delivery of goods (right). The top rear module is used in the passenger configuration only. The rest of the chassis is the same per the two configurations. The requested flexibility consists on introducing or not the top rear module.

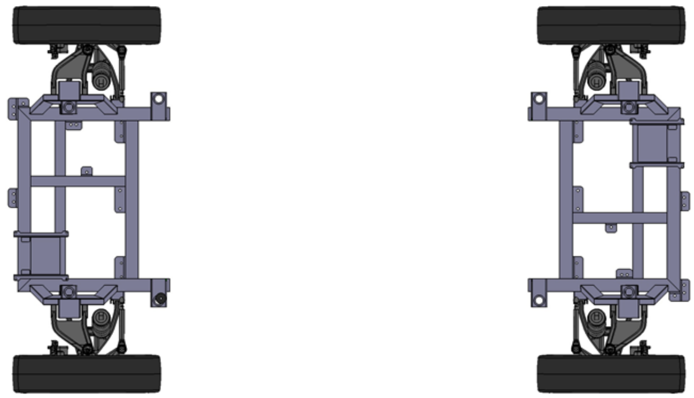


Figure 4 : Axle frame: Within the purpose of this project the axle frame is identical for both the front and the rear motorized axles and for both the passenger and the cargo configurations.

Material handling: requested flexibility

All elements composing the sub modules of the chassis and of the axle frame are laser marked and stored in the vicinity of the welding-assembling cells. Referring to figure 3 the selection of one vehicle configuration (passenger) to the cargo configuration does not demand other flexibility than the decision to produce or not the top rear module.

Labour: requested flexibility

Until the full potential of the assembly line will be met, the production will be characterized by rather low volume specialized productions characterized by:

- Variable-demand manufacturing,
- High-mix manufacturing,
- Manufacturing per which non-recurring engineering costs become a large portion of the overall product cost,
- Rate-dependent production.

In this context and with all processes operated manually the operators should be able to complete different tasks in order to have good results in terms of quality and efficiency. The people operating the line needs to be multi-skilled with a high attitude to collaborate and pass from one process (competence) to another.

Although the assembly line is still to be completed the idea is to operate it in Compliance with ergonomic and health standard principally referring to ISO TS 15066.

4.1.3 "TO BE"

Production system lifecycle phase

Preliminary considerations are limited to the Planning and Engineering Phase.

In particular, the following requirements have been identified:

- selection and recruitment of multi-skilled workforce: the move from the manual to more automated cells (working areas) until the line will not be operated under its full capability (low volumes) will continue to require multi-skilled operators.
- need to train workforce in the CPS:

Almost all employees of the mobility compartment are going to be touched by CPS. While basic engineering knowledge (power train, battery designs, chassis, materials selection etc.) remains fundamental, engineers must also be able to design, develop, and test systems that include communication and sensing technologies and more sophisticated computer controls. These new skills are especially important in new applications such as electrification, vehicle-to-vehicle communication, active safety features, and automated or autonomous driving. So far I-FEVS has been successful in providing the necessary training, but, looking ahead, I-FEVS expect that employees will enter with a stronger foundation in CPS.

The Supply Chain Manager will plan, coordinate and monitor the transfer of goods and materials from manufacturers and suppliers all the way through to customers considering the different configuration of the vehicle. The quality engineer will use quality assurance and control of processes as well as products to achieve more consistent quality in both vehicle configurations.

All the operators will be able to use different tools and systems of the Micro-Factory to switch easily from the passenger vehicle configuration to the delivery of goods configuration.

The Product engineer will be the technical interface between the component development team and the production side (Front End and Back End), especially after the development phase and qualifications when the high volume production is running. Product engineer will improve the product quality and secure the product reliability by balancing cost of test and test coverage that could impact the production fall-off especially finding the best solutions for the production mix of vehicles.

The maintenance technician will: be responsible for the completion of all maintenance service requests as assigned, assure optimization of the structure, analyze repetitive equipment failures, estimate maintenance costs and evaluate alternatives, schedule and complete the "Preventative Maintenance Program" of the system taking into account both the two possible configurations of the production line.

Approach to mitigate the low volume specialized productions characterized by:

- Variable-demand manufacturing,
- High-mix manufacturing,
- Manufacturing per which non-recurring engineering costs become a large portion of the overall product cost,
- Rate-dependent production.

As seen from the I-FEVS-Polimodel point of view the micro factory includes a total of 12 automated cells (working areas) operated in a cloud in which the full processes are interlinked aiming at their optimization (each cell is learning from the operation of others and self-adapts to minimize energy use and tune the parameters for optimal welding-assembly), and where all data are managed and recorded aiming at providing outputs to the supply chain as well as the goal of 100% tracking of all manufacturing processes.

All the operators will be able to manage the system and collaborating with the feedback given by the quality engineer they will correct the automation.

CPPS state (production)

To mitigate the variability related to low volume specialized productions we also envision the adoption of plug and play hardware - software to implement the cloud-based CPS architecture with services aimed at predictive maintenance methods, supported by knowledge based concepts of self-learning and self-adaptation.

At full capacity the factory will have a CPS architecture that self-adapts and self-optimize thanks to the feedbacks given by the operators, the quality engineer and the various sensors placed in the working areas.

To overcome the current limited IT related knowledge available I-FEVS and Polimodel will at first rely on the partners' support and eventually, after the project will be concluded, with in mind to continuously update the performance of the automated line, part of the ICT infrastructure might be outsourced to specialized companies. Both I-FEVS and Polimodel are in any case committed to grow the concept of the microfactory concept as applied to Micro Electric Vehicles keeping the expertise of the ICT related platforms as much as possible internally.

4.1.4 Highlights

Multi skilled employees and ICT-competent employees seem to be critical factors for humans to become flexibility drivers but the detailed scenarios have not been developed yet in this task, but will be shown in the next months thanks to the collaboration I-FEVS Comau Polimodel.

4.2 GKN

4.2.1 Production system

The system subject to be the Use Case for developing and demonstrating PERFoRM is located in Trollhatten.

The Use Case will directly involve:

- 1 Supervisor
- x Operators

Furthermore, other 4 roles will be indirectly impacted:

- 1 Quality engineer
- 1 Maintenance manager
- 1 Maintenance technicians
- 1 Project engineer

The production system is organized as a job shop to manufacture the following main parts :

- Vane
- Hub segment
- Shroud segment
- Blades
- Airduct

4.2.2 "AS IS"

The organization is close to the STS: task cycle time is 3-5 hours and require high skills. Task identity is very high, standardization limited. Workers are trained to do several operations and can operate different machines.

Flexibility requirements concern:

- Volume, rather high: volumes can vary +/-20-50%
- Variety, rather low: 100 parts within 20 types (value stream).
- Process. Machines are not dedicated but require 1-3 set up/hour.
- Labour flexibility appears to be significant.

The production system is already very flexible, the need is to safeguard mix flexibility while increasing efficiency through automation.

The company monitors sick leave and worker satisfaction:

- Safety/incidents
- Safety/lost work days
- Employee Survey (PCI Positive Climate Index)

4.2.3 "TO BE"

Several challenges and opportunities have been identified with interesting implication for the role of humans in the envisioned TO BE scenarios, with reference to different perspectives:

Factory Lifecycle

With reference to the factory lifecycle, several aspects have been underlined in B.

In particular, it is interesting to underline some of them:

- a change of mind-set required in the Planning and Engineering phase for all the involved roles to introduce re-configurability concepts since the beginning;
- the design of the manufacturing system (micro flow cell) architecture and the definition of appropriate standards is cornerstone.
- people involved in industrialization (engineers and purchasing) need to steer and adapt their activity to foster the re-use of the micro flow cell
- and people involved in the ramp-up contribute to reducing time and costs

Production states

Several considerations have been raised with reference to the production states in B.

In particular the following can be highlighted:

- design of self-check/test/calibration features (see involved roles)
- enhanced planning/scheduling methods (more competent scheduler and/or support of simulation)
- competence/flex training and supporting HMI for operators for dealing with complexity/variety, resolve problems, etc.

Management activities

Challenges and opportunities related to the TO BE scenarios have been described also with reference to the different types of management activities in B

4.2.4 Highlights

The introduction of CPPS should be associated with a shift in the long-term perspective. Planning and engineering activities should aim at incorporating adaptability and re-configurability concepts and features in the methods and in the systems.

The adoption of CPPS and semi-automated cells have several implications: increased automation and support for the operators, on the one hand; higher and novel requirements for competences and flexibility for several roles in the factories.

4.3 SIEMENS

4.3.1 Production system

The system subject to be the Use Case for developing and demonstrating PERFoRM is located in the Duisburg Plant, in particular in the Manufacturing Department.

The Siemens Duisburg plant produces industrial compressors (axial and radial), especially turbo compressors and it is organized as a job shop. An overview of the site is given in Figure 5. The fabrication and assembly of the compressors takes place in the main production hall. All required main processes are concentrated in this building. Directly next to the building a test-center is located, capable of testing turbo-compressors incl. all auxiliaries (motor, gearbox, protective gas system, etc.) under operating conditions. Some smaller subcomponents and parts are fabricated in a separate building besides the main production building. On site also offices (incl. e.g. order engineering) and a service and training centre can be found. The plant is directly connected to a harbour and to the rail system. As assembled compressor systems can easily reach the size of a family home and weigh up to 700 tons, road logistics would be impossible for large parts of the production.

Figure 5: Duisburg plant overview

A detailed view of the main production building layout can be found in Figure 6. All areas marked can include multiple machineries. Several information terminals (PC based) are placed at central locations.

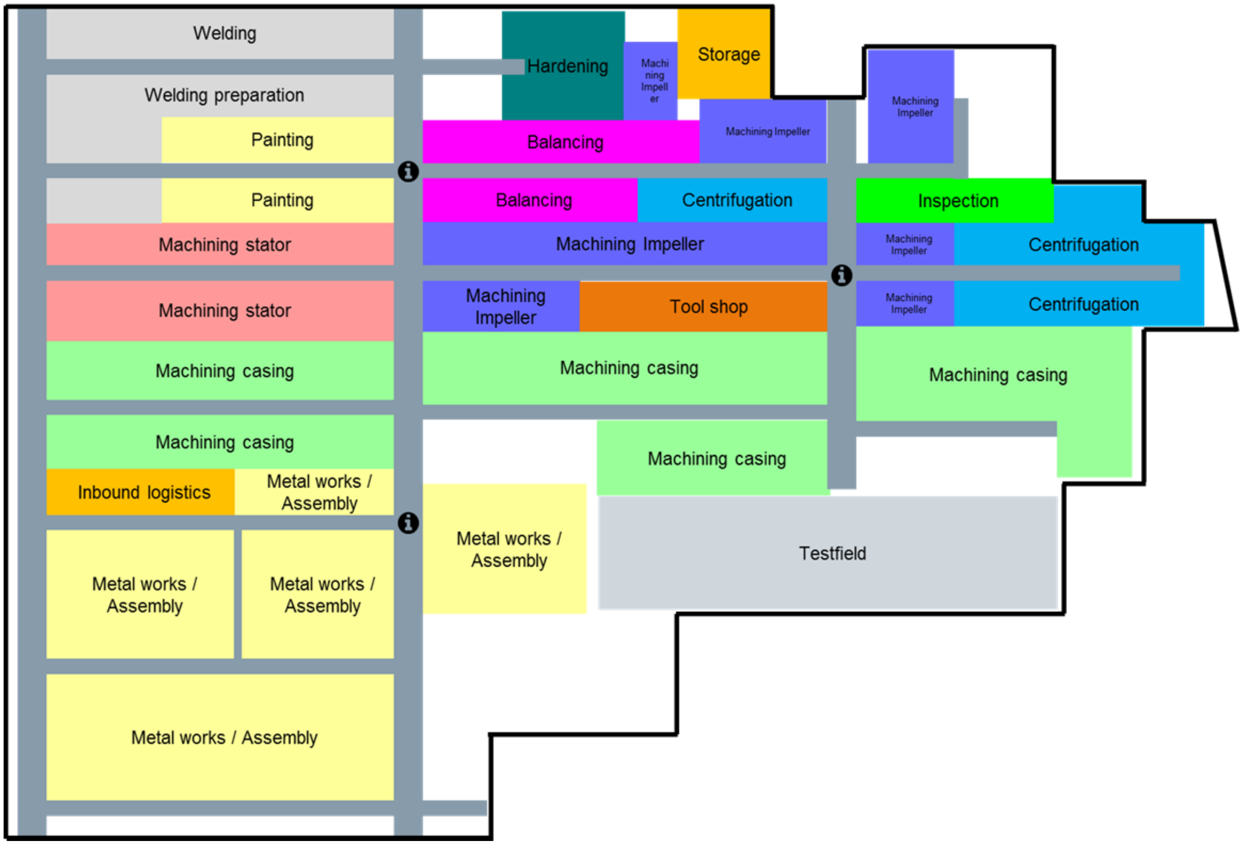


Figure 6: Shop floor Layout

The Use Case involves directly 5 main roles:

- Technology solutions lead (responsible for manufacturing technology solutions, e.g. robots and machinery)
- IT lead (responsible for manufacturing IT)
- Maintenance lead (responsible for maintenance in the whole plant)
- Shift supervisors (responsible for the daily production incl. scheduling)
- operators (operating the manufacturing equipment and producing the products)
- Maintenance personal (responsible for processing maintenance task on plant equipment)

Furthermore, the Use Case indirectly involves the following management roles.

- Manufacturing Manager
- Plant Manager
- Assembly Management (Assembly Head, Technology Head, Technology Solutions, CAM technology and Maintenance).

A short description of the above mentioned roles is reported in Appendix I.

4.3.2 “AS IS”

The organizational context is characterized by a high level of teamwork, skill variety and standardization. Usually workers receive feedback from the process. There is no takt time in the factory and cycle times highly depend on the parts to be manufactured. They may span spans from few hours to two weeks (given a two shift system).

Given the high variety of products manufactured at the plant (ETO business, lot size 1,4), all teams have to adapt to ever changing product variances. While Operators are typically specialized on type of machinery, they still need to cope with changing products and merely ever produce two pieces of the same kind after another. The same holds true for maintenance staff which has to cope with all machinery installed on the production system.

Humans are a crucial part of the overall system in terms of flexibility. Although some information can be automatically generated (e.g. CNC code from CAD/CAM models), human operators need to adapt the specific production processes with regards to exact material used, condition of the machine, etc.

The overall production planning is realized at ERP level. The production plans are quite fixed and changes are made by humans (e.g. maintenance manager) directly on the shop floor (e.g. in case of machine breakdown). Thus, the current system leads to quite rigid production schedules, thus partly hindering humans on the shop floor to increase production flexibility.

While a flexible adaptation of machines to ever changing products is currently well covered by a mix of automatic code generation from CAD/CAM models and human operator adjustments, the overall scheduling of the plant needs major improvements. Given the comparably long breakdown and maintenance times and high costs incurred to these, and also the fact that especially real big parts cannot be manufactured on several machineries, but mostly on only one per production step, scheduling needs to be flexibilised and needs to adapt to the current status on the shop floor.

4.3.3 "TO BE"

The emphasis of the TO BE scenario is focused on the production phase. While the other phases of the factory lifecycle do not seem to be impacted by the PERFoRM project.

As described already before, the main challenge within the PERFoRM project will be a quick and flexible adaptation of the production planning and scheduling to production disturbances. This involves mainly the operators and maintenance staff. Additionally, a new role or extension of existing roles might be needed to reflect the responsibilities for re-scheduling. Currently this is done in cooperation by the shift supervisors and the maintenance lead. Given a better flexibility of the production system with respect to disturbances, this task might be concentrated to the shift supervisors in the future.

Currently machine failures, breakdowns and planned maintenance are detected by the machine operator. Depending on the find of incident, he can go to one of the information terminals in order to open a ticket for the maintenance department (maintenance ticket). The information quality of this ticket is highly depending on the individual creating it. Some operators give precise information about failure states and codes the machine showed. Others are mainly reporting a machine breakdown.

These tickets are received by the maintenance personal. Depending on the data quality they may directly know a solution for the problem or may have to go directly to the machine in order to gather more information.

A first part of the To-Be situation would be a coupling of data/information sources to increase the ticket quality. This includes a coupling to central production database where error codes and similar information from the machineries are stored. Also in the future it is required for some factory policies, that the operator goes to the central information terminal in order to open a ticket (and not e.g. directly at on HMI of the machine he is operating). When he opens a new ticket in the system and enters the machine this ticket refers to, the system can automatically detect error codes and other machine related information. It may then ask the operator if he wants to add these information automatically to the system. He may also refuse this in order to open a ticket which may not be directly connected to machine breakdown (e.g. he may have recognized minor problems with machine accuracy and thus request a positioning run). In this way not only operators are supported in the ticket creation process. At the same time maintenance staff will be provided with better and more reliable information regarding the current machine status. In some cases this will provide maintenance personal with the ability to bring directly the spare parts to the machine in order to repair it.

The second step in the To-Be situation would be a self-learning data analytic which is correlating error codes, machine states, sensor and human feedback etc. with disturbances, thus enabling a prediction of these errors. Although this is typically done on a pure technical level, the goal is to include also human observations into the analytics systems. Some of the operators are working for years mainly on the same machine. It has been proven by experience that these operators may predict an inadequate behavior quite well. The goal is to include these human observations into the system in order to better calculate risks of disturbances better and with less additional technical sensing effort.

The last step in the To-Be situation will be the linkage of the information of the first two steps with the plant scheduling system. This includes that planned maintenance and ordered repairs are scheduled to the machines in the same way as production orders. At the same time the scheduling system can react to current disturbances on the shop floor. E.g. if a machine breakdown is detected, the scheduling system might not directly relocate the production order of that machine to other machines. Due to size of the parts and required tolerances, clamping and unclamping might take several hours. If the machine can be repaired within this time a rescheduling of the current order would incur more risks with respect to product quality than it reduces risks of delays. One way to identify re-scheduling might be the feedback from maintenance staff. As soon as it is detected that the breakdown can not be fixed within a short time, this information can be given to the system, or might even be automatically detected (e.g. if the maintenance sets the machine status on “not.-operational” and places a maintenance order to the machine supplier via the ERP system).

The re-scheduling can be foreseen in 3 implementation degrees:

a) the re-scheduling is not done automatically by the system. Only scheduling tasks are created by the system. Results are displayed to the shift supervisor and he is responsible for a correct planning of all production orders, maintenance tasks etc.
b) the re-scheduling is done automatically by the system. Results are shown to the shift supervisor. He ca either accept the proposed schedule or change it manually.

c) the re-scheduling is done automatically by the system. Results are shown to the shift supervisor and are automatically processed to the shop floor. Manual interaction by the shift supervisor is generally not needed but still possible.

Within the project only steps a) and b) are foreseen as results. Possible ways to reach step c) and implications of this degree should be shown.

With reference to the production states, the following have been identified as critical:

- Processing; during processing the maintenance operators should identify and early detect system inadequate behavior.
- Maintenance: the maintenance should be made more effective due to better information quality from the beginning
- Production planning: production planning should be made more flexible especially with respect to production disturbances

Figure 7 gives an overview for the abovementioned proce**ss.**

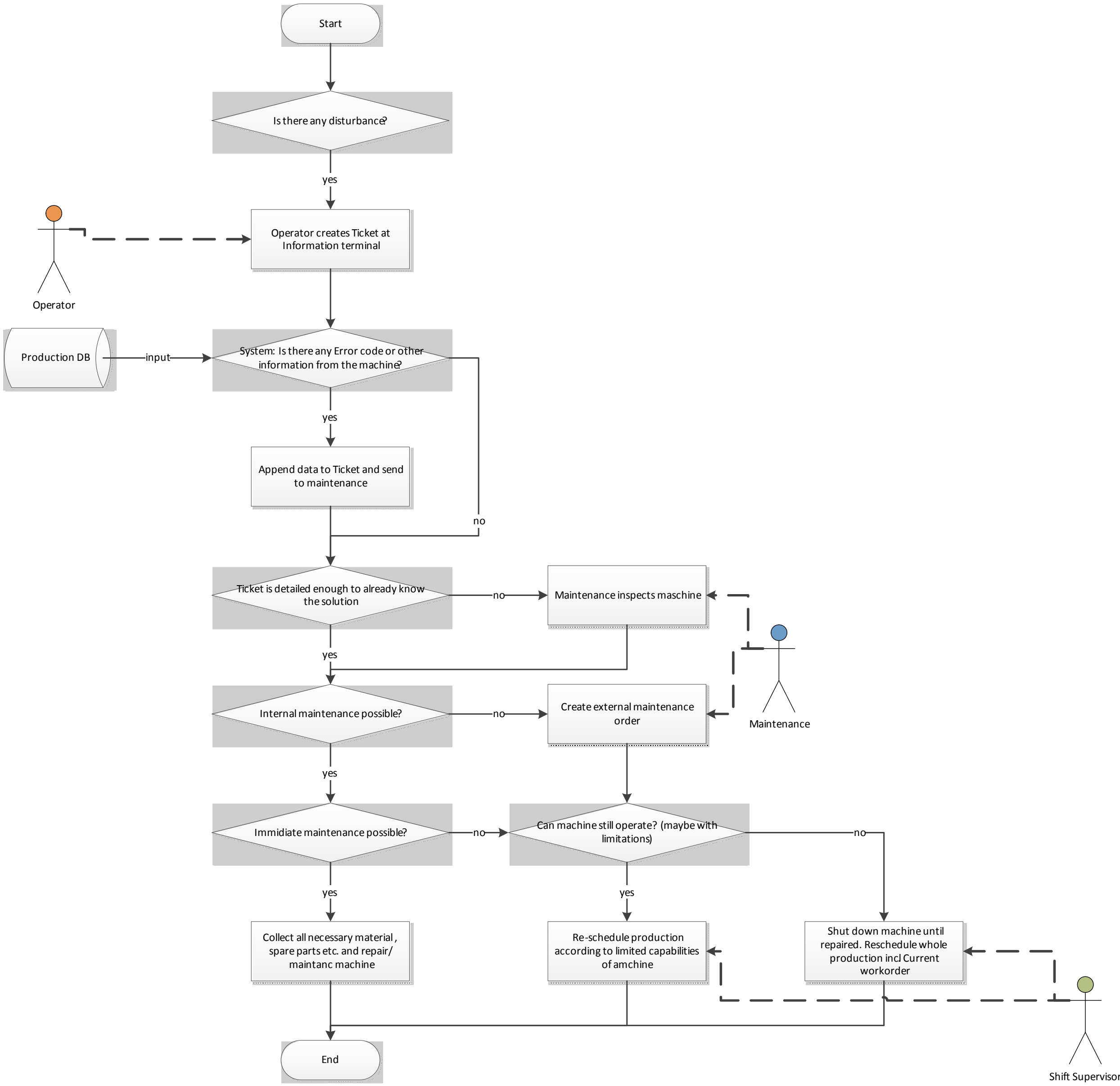


Figure 7: simplified Flow Chart for Disturbance reaction

4.3.4 Highlights

The involved Humans (operators, maintenance personal, shift supervisors) will still play a crucial role in terms of flexibility in the TO BE scenarios, with reference to the joint(or interdependent) scheduling and re-scheduling of production and maintenance activities, taking care of all the interdependent processes (i.e. spare part management). Major progress will be made by system functionalities supporting this flexibility.

4.4 WHIRLPOOL (WHIRLPOOL)

4.4.1 Production system

The system subject to be the Use Case for developing and demonstrating PERFoRM is lthe Entore Value Stream Primary Process and the assembly line, located in the Microwaves Oven Plant in Cassinetta.

The line produces 4 main families of microwave ovens:

- Mini
- MIDI
- Opera
- Phoenix

The Use Case directly involves 180 employees:
30 Equipment Assistants of the Primary Processes, who supervise equipment load and unload of parts
150 Assembly Operators, who assemble parts and test products on the continuous assembly line

Furthermore, the Use Case indirectly involve more roles and people, as reported in I.

4.4.2 "AS IS"

The Whirlpool Production system is inspired by the Lean system, with flow production and short cycle time (50 sec.), high standardization, feedback and workers' participation to continuous improvement.

Flexibility needs have not been highlighted as a relevant requirement for the PERFoRM Use Case.

Production performances seem to be mostly directed to efficiency (OEE) and to the actualization of the plans.

With reference to social performances, the company aims at objectives that go beyond the pure compliance with existing regulation. Through internal policies, the Social Responsibility and other initiatives, health & safety, workers' wellbeing and involvement are pursued.

4.4.3 "TO BE"

The challenges and opportunities have been identified with reference to the phases of the production system lifecycle after the line has been planned and engineered.

Knowledge/experience transfer, training, full application of standards and procedures have been identified among the most relevant topics.

4.4.4 Highlights

The main opportunities have been identified in relationship to supporting the humans in sharing, transferring, developing knowledge for the adaptation or reconfiguration of a production line, in order to quickly achieve the performance target and the compliance with the Whirlpool manufacturing systems.

Furthermore, training in industry, has been emphasized as a relevant requirements, to provide the workers with the necessary knowledge and skills for the ramp-up phase.

5 Gap analysis and recommendations

5.1 Gap analysis

The gap analysis requires the detailed description and study of the human activities in the TO BE scenarios.

The PERFoRM use cases, as characterized and partially analysed in section 4 have a quite wide scope, involving several human roles, under different circumstances and have not specified enough to support a thorough analysis, by the date of delivery of the present document.

However, leveraging on the literature on humans and CPS in manufacturing, two main types of scenarios have been outlined and instantiated with few significant scenarios selected by each use case partner.

The first type of scenario is referred to human roles operating at the level of CPSs, while the second type of scenario is referred to the level of higher ICT systems, as illustrated in Figure 8 - Types of scenarios with reference to the Architectural view, with reference to the PERFoRM Framework of the Project (SIEMENS, 2016). The two types of scenarios can be seen in relationship with the levels of ISA 95, as illustrated in Figure 9 - Types of scenarios with reference to the ISA 95 standard.

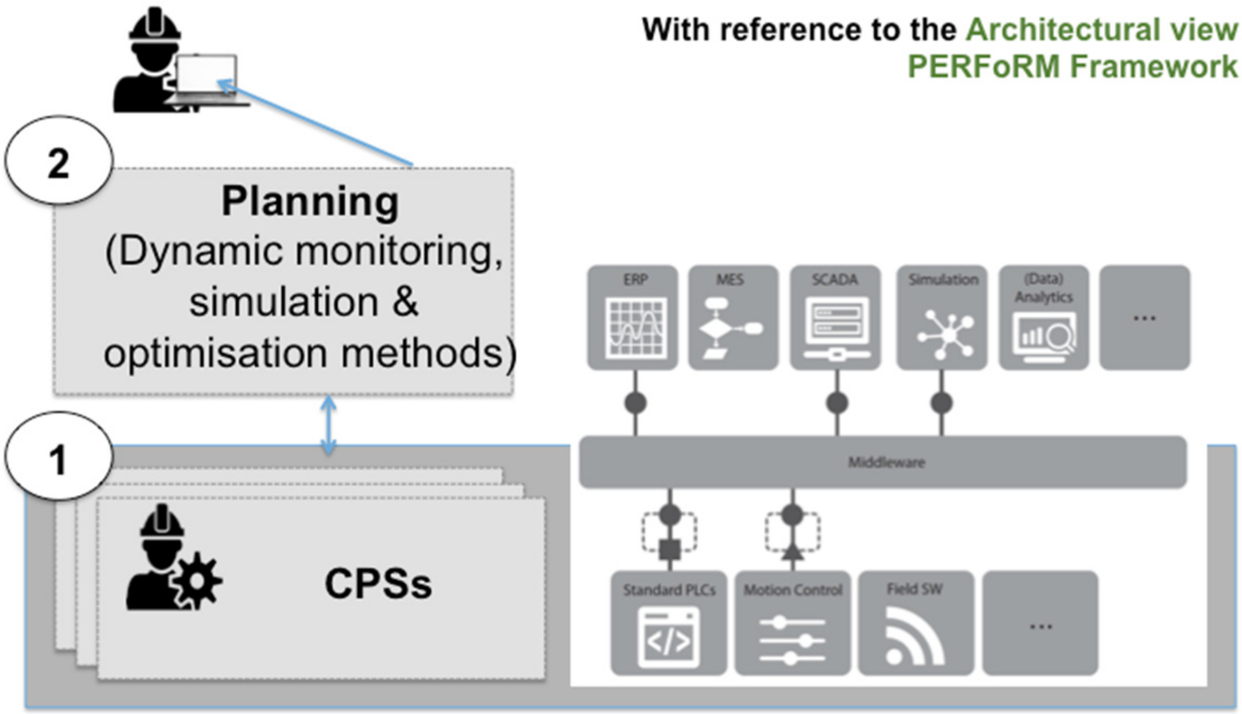


Figure 8 - Types of scenarios with reference to the Architectural view

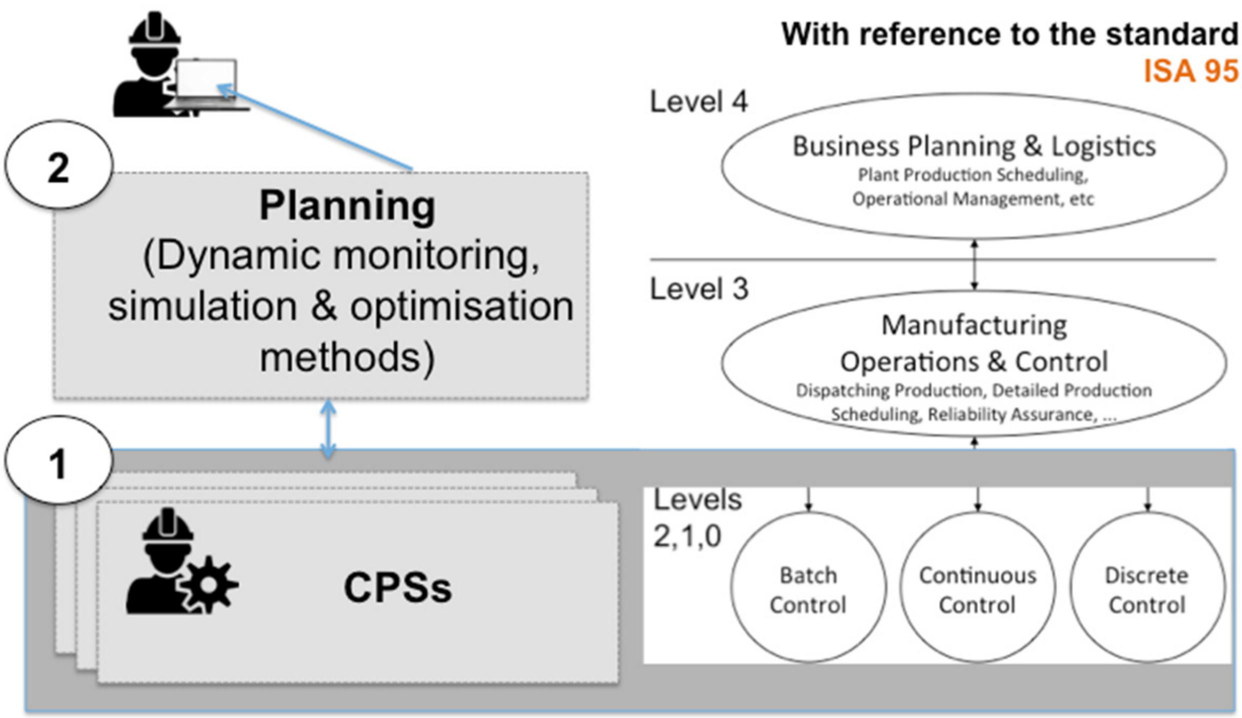


Figure 9 - Types of scenarios with reference to the ISA 95 standard

The first type of scenario corresponds to the Human-in-the-Loop situation (Sousa Nunes, Zhang, & Sà Silva, 2015), the second scenario, inspired by future visions of CPS i.e. (Foundations for Innovation in

Cyber Physical Systems, 2015)), has been named Human-in the-Mesh to emphasize the reconfigurable networked nature of human-interactive CPPs.

The **Human-in-the-Loop** (HiL) types of scenarios may involve different types of human activities susceptible to influence the overall performance and bring flexibility to the system, as illustrated in Figure 10 Human-in-the-Loop: human activities.

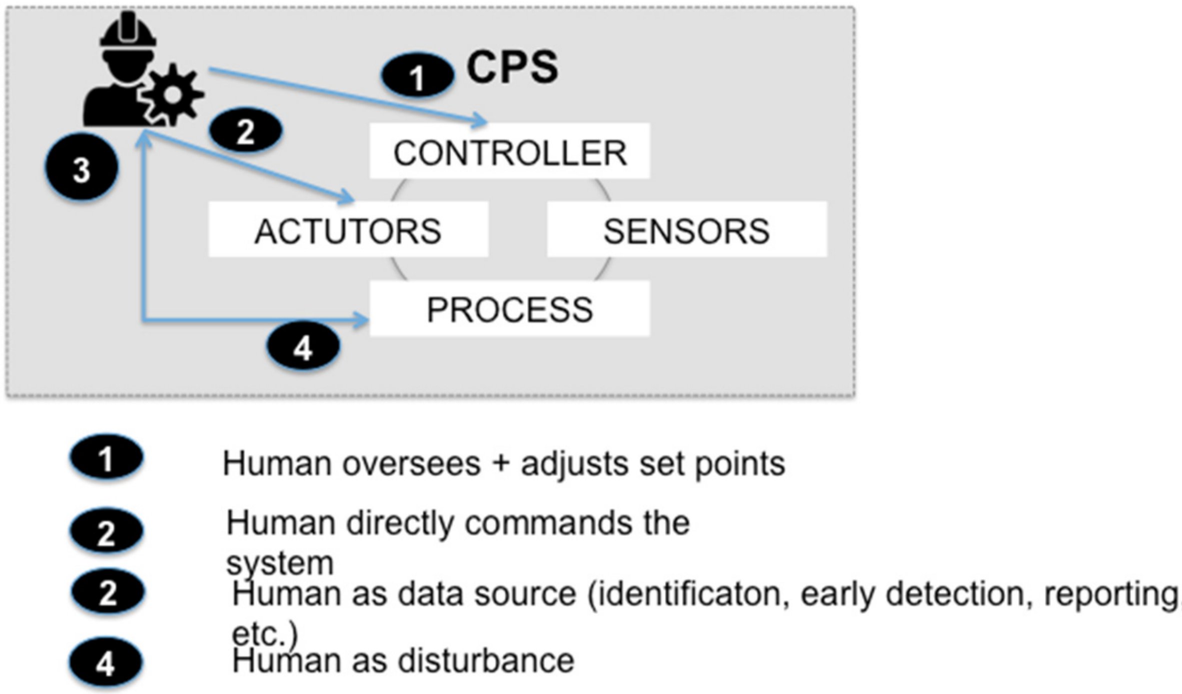
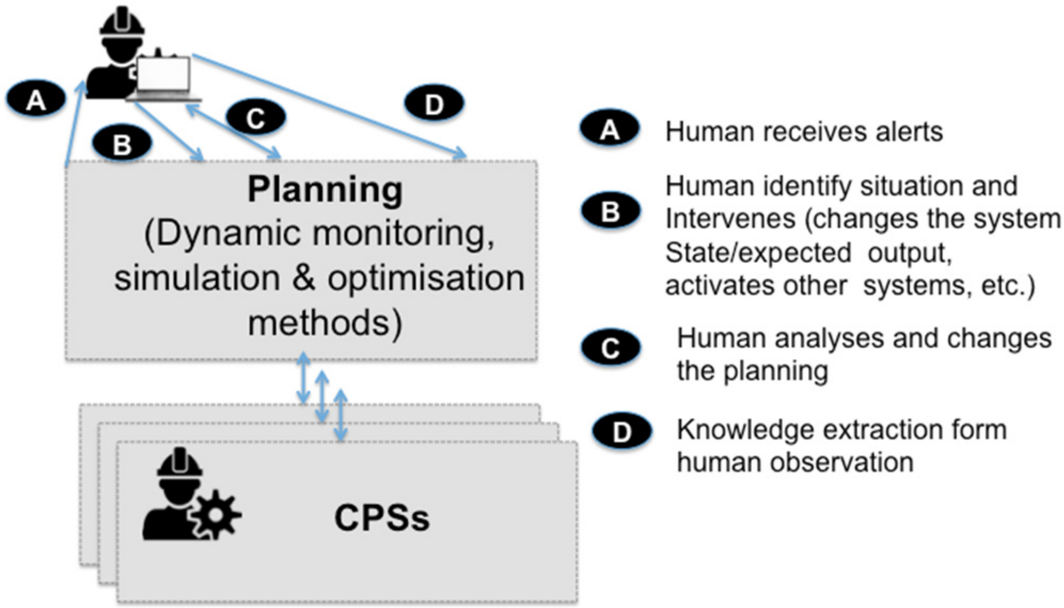


Figure 10 Human-in-the-Loop: human activities

The Human-in-the-Mesh (HiM) scenarios may involve different types of human activities, related to the interactions with the CPS network and applications, including supported interaction with other human roles.

While the HiL type of scenario has been studied in different application domains, the HiM can be considered as an emerging model, still undefined and not well understood.

However, some types of human activities that may influence the performance and the flexibility of the manufacturing systems have been preliminary identified and represented in Figure 10 Human-in-the-Loop: human activities.



The use case partners have analysed some significant scenarios of their use case, according to the framework provided by the HiL and HiM types.

The selected scenarios are quite scattered along the different lifecycle phases of the manufacturing system (from left to right in the table) and of the production states (from the top to the bottom in the table), as illustrated in Figure 11 Selected scenarios coverage of the Lifecycle phases and Production states. Although they do not encompass all the scope for each use case, as a whole they offer a satisfactory coverage of the area of investigation.

This analysis should therefore be considered as a first step aiming, on the one hand, at validating the framework of analysis and, on the other hand, at achieving valuable although partial results.

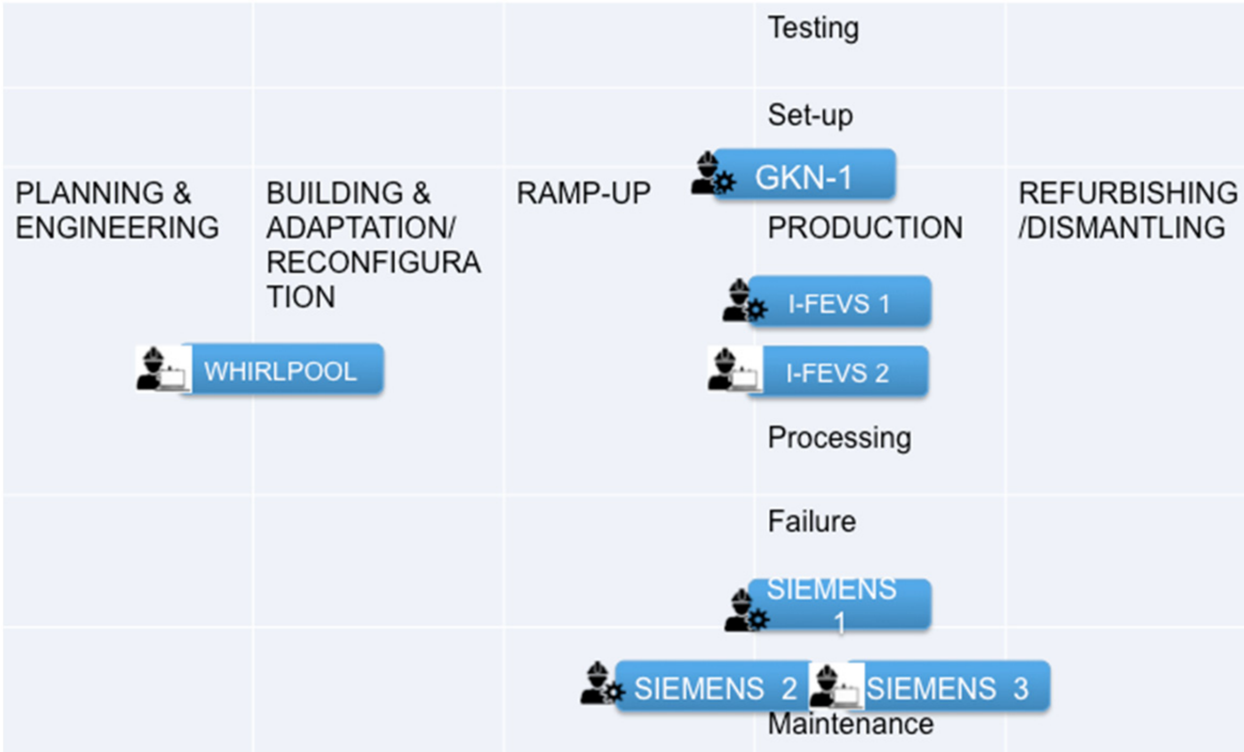


Figure 11 Selected scenarios coverage of the Lifecycle phases and Production states

The analysis of the scenarios has been performed starting from the critical human activities, according to the categories identified for HiL and HiM.

For each critical human activities, the performances have been identified that are influenced both in a positive or negative way. On that basis, possible issues, barriers or enabling factors have been recognized and shortly described.

The analysis for each use case and selected scenario is reported in III **APPENDIX - ANALYSIS OF SELECTED SCENARIOS WITHIN THE USE CASES**.

5.2 Recommendations

The analysis of the individual scenarios has led to the elaboration of a set of specific preliminary recommendations elaborated in order to overcome the issue and reinforce the positive factors that allow human activities to improve manufacturing performances and enhance flexibility, reported in III **APPENDIX - ANALYSIS OF SELECTED SCENARIOS WITHIN THE USE CASES**.

These recommendations have been analysed and classified per type of scenario and type of solutions concerned.

5.2.1 Human-in-the-Loop Recommendations

Organizational

- Skill/job flexibility
- Competences to operate robots
- Process competences (i.e. welding)
- ICT competences (MES)
- TPM (Total Productive Maintenance) approach
- Quality (analysis) competences
- Consultation among colleagues
- Feedback mechanism to the operator to support valuable behaviour and discourage non-valuable

Methods

- Routine training
- Instructions
- Error proofing design
- Human task monitoring + alerts in case of possible errors
- CPS monitoring + alerts in case of unexpected/anomalous events or behaviour,
- Condition-based instruction to support diagnosis and reporting and to guide interventions
- Context-aware guidance to prepare interventions (i.e. tools and spare parts for maintenance)
-

Technological

-
- Mobile devices with context aware (role, location) support
- Support visual inspection with sensors
- Support testing (geometrical, power train, fatigue, etc.)
- Virtual presence (for consulting expert colleagues: sharing view, screen, info, voice connection or chat?)
- Multimodal interaction (voice, image, gesture recognition, sound lights, etc,) to alert and to support field work

- Suitable/wearable device to support field work
- Asset tracking (tools and spare parts).
- Localization and turn by turn navigation to retrieve machine, tools, spare parts.

5.2.2 Human-in-the-Mesh Recommendations

Organizational

- Competences in complex systems modelling and simulation
- Skills/training in in decision making
- Alignment of responsibility and authority (i.e. rescheduling orders to the supply chain)
- Alignment of the objectives and incentives with desired performances
- Knowledge transfer from experts to less experts decision makers

Methods

- Incremental models, evolving with the skills and knowledge sharing of the humans
- Multi-objective (multi-stakeholder) decision making
- Caption of decision making patterns by experts

Technological

- Mobile, context aware (role, location) support
- Intuitive representation of alternatives and trade-offs
- Decision support enhanced by experts' decision making patterens

6 Conclusions and outlook

This document summarizes the results of the effort dedicated in the very first months of the PERFoRM project to understand and recommend solutions to take advantage of humans as flexibility drivers in cyber physical production systems, in general, and in the PERFoRM use cases, in particular. This activity has been developing in parallel with the collection and analysis of the project requirements, performed within work-package 1. It is therefore comprehensible that in this early stage of the project, both the definition of the use case scenarios and the specification of the functionalities of the technological solutions developed by PERFoRM were still in an initial phase and rather fuzzy. However, thanks to the joint effort of use case partners as well as the other partners involved in this task, some conclusions have been achieved:

- two models of scenarios have been defined to describe Human-in-the-Loop and Human-in-the-Mesh roles;
- challenges and opportunities, barriers and enablers for the human role has been analysed with reference to the scenarios models and the instantiation for specific scenarios of the project use cases
- recommendations addressing organizational, methodological and technical aspects have been elaborated.

These conclusions have to be considered as preliminary. When all the details of the future scenarios are detailed, it will be possible to further investigate and reflect on the implications for the human role under different circumstances (manufacturing systems' lifecycle, production states).

In the next months, as the development of the project progresses, the work will continue through further iterations to describe in detail the main use case scenarios, and to analyse the human activities.

This will allow the refinement and validation of the Human-in-the-loop and Human-in-the-Mesh framework and the related types of human activities.

Furthermore, the effort will be finalized towards the identification of comprehensive lists of challenges and opportunities, barriers and enablers for each type of activity, which might be general enough to be used as a basis for the development of guidelines to foster the successful integrations of humans in CPPS and towards the finalization of the recommendations.

The final results of this stream of activity will be included in a following deliverable of WP2, D2.5 "Guidelines for seamless integration of Humans as flexibility driver in flexible production systems, 2nd iteration", which will be issued at M18.

I. APPENEDIX – Social Performance Indicators (SO SMART project)

Class	Subclass	ID	Para-meters	Short Description	Related Beneficiary Groups (indicatively)	Measurability 3-qualitative 2-rate, ratio, calculable 1-quantitative, parameters	Source
Labor	Employment	LA 1	pcs, rate	Total number and rates of new employee hires and employee turnover by age group, gender and region	factory, society	2	GRI 4
Labor	Employment	LA 2		Benefits provided to full-time employees that are not provided to temporary, rented or part-time employees, by major operations.	employee, factory	3	GRI 4
Labor	Employment	LA 3	percentage	Return to work and retention rates after parental leave by gender	factory	2	GRI 4
Labor	Labor/Management Relations	LA 4	days	Minimum notice periods regarding operational changes, including whether these are specified in collective agreements	employee, factory	2	GRI 4
Labor	Occupational Health and Safety	LA 5	percentage	Percentage of total workforce represented in formal joint management - worker health and safety committees that help monitor and advise on occupational health and safety programs	employee, factory	2	GRI 4
	Occupational Health and Safety	LA 6	percentage	Type of injury and rates of injury, occupational diseases, lost days, and absenteeism,	factory, employees	2	GRI 4

				and total number of work-related fatalities by region and by gender			
Labor	Occupational Health and Safety	LA 7		Workers with high incidence or high risk of diseases related to their occupation	employee	3	GRI 4
Labor	Occupational Health and Safety	LA 8		Health and safety topics covered in formal agreements with trade unions	factory	3	GRI 4
Labor	Training and Education	LA 9	hours, days	Average hours of training per year per employee by gender, and by employee category	employee, factory	2	GRI 4
Labor	Training and Education	LA 10	number	Programs for skills management and lifelong learning that support the continued employability of employees and assist them in managing career endings.	employees	1	GRI 4
Labor	Training and Education	LA 11	percentage	Percentage of employees receiving regular performance and career development reviews by gender and by employee category	employee	2	GRI 4
Labor	Diversity and Equal Opportunity	LA 12		Composition of governance bodies and breakdown of employees per category according to gender, age group, minority group membership, and other indicators of diversity	factory	3	GRI 4
Labor	Equal Remuneration for Women and Men	LA 13	percentage	Ratio of basic salary and remuneration of men to women by employee category, by significant	employee	2	GRI 4

				locations of operation			
Labor	Supplier Assessment for labor practices	LA 14	percentage	Percentage of new suppliers that were screened using labor practices criteria	society	2	GRI 4
Labor	Supplier Assessment for labor practices	LA 15		Significant actual and potential negative impacts for labor practices in the supply chain and actions taken	society	3	GRI 4
Labor	Labor Practices Grievance Mechanisms	LA 16	pcs	Number of grievances about labor practices filed addressed, and resolved through formal grievance mechanisms	factory	1	GRI 4
Human Rights	Investments	HR 1	percentage	Total percentage and number of significant investment agreements that include human rights clauses or that have undergone human rights screening.	society	2	GRI 4
Human Rights	Investments	HR 2	hours	Total hours of employee training on human rights policies and procedures concerning aspects of human rights that are relevant to operations, including the percentage of employees trained.	employee, factory	1	GRI 4
Human Rights	Investments	HR 3	pcs	Total number of incidents of discrimination and corrective actions taken	factory, society	1	GRI 4
Human Rights	Freedom of Association and collective Bargaining	HR 4		Operations and suppliers identified in which the right to exercise freedom of association and collective bargaining may be violated or at significant risk,	factory, society	3	GRI 4

				and measures taken to support these rights			
Human Rights	Child labor	HR 5		Operations and suppliers identified as having significant risk for incidents of child labor, and measures taken to contribute to the effective abolition of child labor	factory, society	3	GRI 4
Human Rights	Forced or compulsory labor	HR 6		Operations and suppliers identified as having significant risk for incidents of forced or compulsory labor, and measures to contribute to the elimination of all forms of forced or compulsory labor	factory, society	3	GRI 4
Human Rights	security practices	HR 7	percentage	Percentage of security personnel trained in the organization's human rights policies or procedures that are relevant to operations	employee, factory	2	GRI 4
Human Rights	indigenous rights	HR 8	pcs	Total number of incidents of violation involving rights of indigenous peoples and actions taken	factory, society	1	GRI 4
Human Rights	assessment	HR 9	pcs	Total number and percentage of operations that have been subject to human rights reviews or impact assessments	factory	1	GRI 4
Human Rights	supplier human rights assessment	HR 10	percentage	Percentage of new suppliers that were screened using human rights criteria	factory, society	2	GRI 4
Human Rights	supplier human rights assessment	HR 11		Significant actual and potential negative human rights impacts in the supply	factory, society	3	GRI 4

				chain and actions taken			
Human Rights	human rights grievance mechanisms	HR 12	pcs	Number of grievances about human rights impacts filed, addressed and resolved through formal grievance mechanisms	factory, society	1	GRI 4
Social	local communities	SO 1	percentage	Percentage of operations with implemented local community engagement, impact assessments and development programs	society	2	GRI 4
Social	local communities	SO 2		Operations with significant actual and potential negative impacts on local communities	society	3	GRI 4
Social	anti-corruption	SO 3	number	Total number and percentage of operations assessed for risks related to corruption and the significant risk identified	factory	1	GRI 4
Social	anti-corruption	SO 4		Communication and training on anti-corruption policies and procedures	employee	3	GRI 4
Social	anti-corruption	SO 5	number	Confirmed incidents of corruptions by country and recipient/beneficiary	society	1	GRI 4
Social	Public policy	SO 6		Total value of political contributions by country and recipient/beneficiary	society	3	GRI 4
Social	anti-competitive behaviour	SO 7	number	Total number of legal actions for anti-competitive behavior, anti-truct, and monopoly practices and their outcomes	society	1	GRI 4
Social	compliance	SO 8	cost	Monetary value of significant fines and total number of non-monetary sanctions for non-compliance	factory, society	2	GRI 4

				with laws and regulations			
Social	supplier assessment for impacts on society	SO 9	percentage	Percentage of new suppliers that were screened using criteria for impacts on society	society	2	GRI 4
Social	supplier assessment for impacts on society	SO 10		Significant actual and potential impacts on society in the supply chain and actions taken	society	3	GRI 4
Social	grievance mechanisms for impacts on society	SO 11	number	Number of grievances about society filed, addressed and resolved through formal grievance mechanisms	society	1	GRI 4
Social	Commitment	SO 12		Commitment to take action in support of social sustainability	factory	3	
Social	Individual career	SO 45	years	Tenure length	employee, factory	1	
Social	Individual career	SO 46		Learning rate	employee	3	
Social	Individual career	SO 47	years	Job-related experience in years	employee	1	
Social	Individual career	SO 48	cost	Training costs	factory	1	
Social	Worker wellbeing	SO 49		Feel-of-control (sense of responsibility)	employee	3	
Social	Worker wellbeing	SO 50		Self-confidence	employee	3	
Social	Worker wellbeing	SO 51		Self-efficiency	employee	3	
Social	Worker wellbeing	SO 52		Job motivation	employee	3	
Social	Worker wellbeing	SO 53		Job satisfaction	employee	3	
Social	Individual career	SO 54		Task-related skills	employee	3	
Social	Individual career	SO 55		Professional knowledge and experience	employee	3	
Social	Collaboration	SO 56		Cooperation skills	employee	3	

II. APPENDIX – Questionnaires gathered from the Use Cases

This section is grounded on the content of the questionnaires completed by the Use Case partners and reported in the document.

A. I-FEVS

Production harmonizEd Reconfiguration of Flexible Robots and Machinery

Horizon 2020 – Factories of the Future, Project ID: 680435

Template to collect organizational needs, challenges and opportunities

T2.1 Guidelines for seamless integration of Humans as flexibility driver in flexible production systems

Lead Author: POLIMI

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Summary

1. INTRODUCTION 54
2. SCOPE AND BOUNDARIES 54
3. ORGANIZATIONAL CONTEXT 57
4. FLEXIBILITY NEEDS 58
5. SOCIAL NEEDS 60
6. PERFORMANCE INDICATORS (SEE APPENDIX) 61
7. CHALLENGES AND OPPORTUNITIES FOR THE HUMAN ROLE TO BE 62
A. APPENDIX 66

1. INTRODUCTION 7
1.1. OBJECTIVES AND SCOPE 7
1.2. INTEGRATION WITHIN THE PROJECT ACTIVITIES 7
1.3. STRUCTURE OF THE DOCUMENT 7
2. METHODOLOGICAL APPROACH 8
3. PRODUCTION SYSTEMS CHARACTERIZATION 9
3.1. PRODUCTION SYSTEMS, PHASES AND STATES 9
3.2. PRODUCTION ACTIVITIES AND ROLES 11
3.1.1 Production activities and roles *11*
3.1.2 Maintenance Management & Scheduling *15*
3.3. SOCIO-TECHNICAL SYSTEMS AND LEAN PRODUCTION SYSTEMS 18
3.4. FLEXIBILITY PERFORMANCES IN PRODUCTION 19
3.5. SOCIAL/HUMAN PERFORMANCES IN PRODUCTION 20
4 ORGANIZATIONAL FRAMEWORK AND ANALYSIS OF REQUIREMENTS, CHALLENGES AND OPPORTUNITIES FOR EACH USE CASE 21
4.1 I-FEVS 21
4.1.1 Production System *21*
4.1.2 "AS IS" *22*
4.1.3 "TO BE" *23*
4.1.4 Highlights *25*
4.2 GKN 25
4.2.1 Production system *25*
4.2.2 "AS IS" *26*
4.2.3 "TO BE" *26*
4.2.4 Highlights *27*
4.3 SIEMENS 28
4.3.1 Production system *28*
4.3.2 "AS IS" *30*

4.3.3 "TO BE" ... *31*
4.3.4 Highlights ... *34*
4.4 WHIRLPOOL (WHIRLPOOL) ... 35
4.4.1 Production system ... *35*
4.4.2 "AS IS" ... *35*
4.4.3 "TO BE" ... *35*
4.4.4 Highlights ... *36*

5 GAP ANALYSIS AND RECOMMENDATIONS ... 36

5.1 GAP ANALYSIS ... 36
5.2 RECOMMENDATIONS ... 40
5.2.1 Human-in-the-Loop Recommendations ... *41*
5.2.2 Human-in-the-Mesh Recommendations ... *42*

6 CONCLUSIONS AND OUTLOOK ... 42

I. APPENEDIX – SOCIAL PERFORMANCE INDICATORS (SO SMART PROJECT) ... 44

II. APPENDIX – QUESTIONNAIRES GATHERED FROM THE USE CASES ... 50

A. I-FEVS ... 51
B. GKN ... 68
C. SIEMENS ... 95
D. WHIRLPOOL ... 113

III. APPENDIX - ANALYSIS OF SELECTED SCENARIOS WITHIN THE USE CASES ... 129

A. I-FEVS ... 130
B. GKN ... 134
C. SIEMENS ... 138
D. WHIRLPOOL ... 147

Introduction

The present template aims at collecting information from the Use Cases, relevant to the purposes of Task 2.1, that is developing Guidelines for seamless integration of Humans as flexibility driver in flexible production systems.

The document is meant to complement the description of the Use Case and the template for the collection of the industrial requirements developed in T1.1 and T1.2 with a special focus on organizational and human aspects.

The template is structured in order to capture:

the scope and boundaries of the use case with reference to the employees directly and indirectly involved;

the characteristics of the industrial context with reference to the culture and organization of work;

the needs for flexibility;

the social needs (safety, wellbeing, etc.)

the performances to be pursued in terms of flexibility and satisfaction of social needs

the indicators to measure the above mentioned performances

the challenges and opportunities for the human role originating from the implementation of CPPS.

The present document represents a first release of a framework that enables a representation of the different organizational settings, needs, challenges and opportunities in a common and comparable manner.

Scope and boundaries

The first step consists in the definition of the organizational scope and boundaries:

T2.1.1 SCOPE AND BOUNDARIES TEMPLATE	
Pilot case:	E-District(I-FEVS/POLIMODEL)
Plant : (1)	Rivoli
Line/Department:	MICRO ELECTRIC VEHICLES

(2)			
Personnel directly involved (3)			
N.	Role	Role description	Organizational unit
1	Supervisor	He supervises the whole process and also plans and schedules the activities	
10	Operators	Do all the manual process and verify the results	
1	Quality engineer	Handles the non-conformity	
Personnel indirectly involved (4)			
N.	Role	Role description	Organizational unit
1	Maintenance technicians	Maintenance of all the machines	
1	Product engineer	Responsible for the process, production preparation and revisions	
Version	Date	Respondent	Validation

Attachment – map of the plant(experimental assembly plant figure 1)

Attachment – layout of the line/department(under definition)

Attachment – organizational structure of the line/department(under definition)

Attachment – organizational structure encompassing all the units directly or indirectly involved (under definition -currently the personnel involved in the assembly line refers directly to the general director of the 2 companies involved)

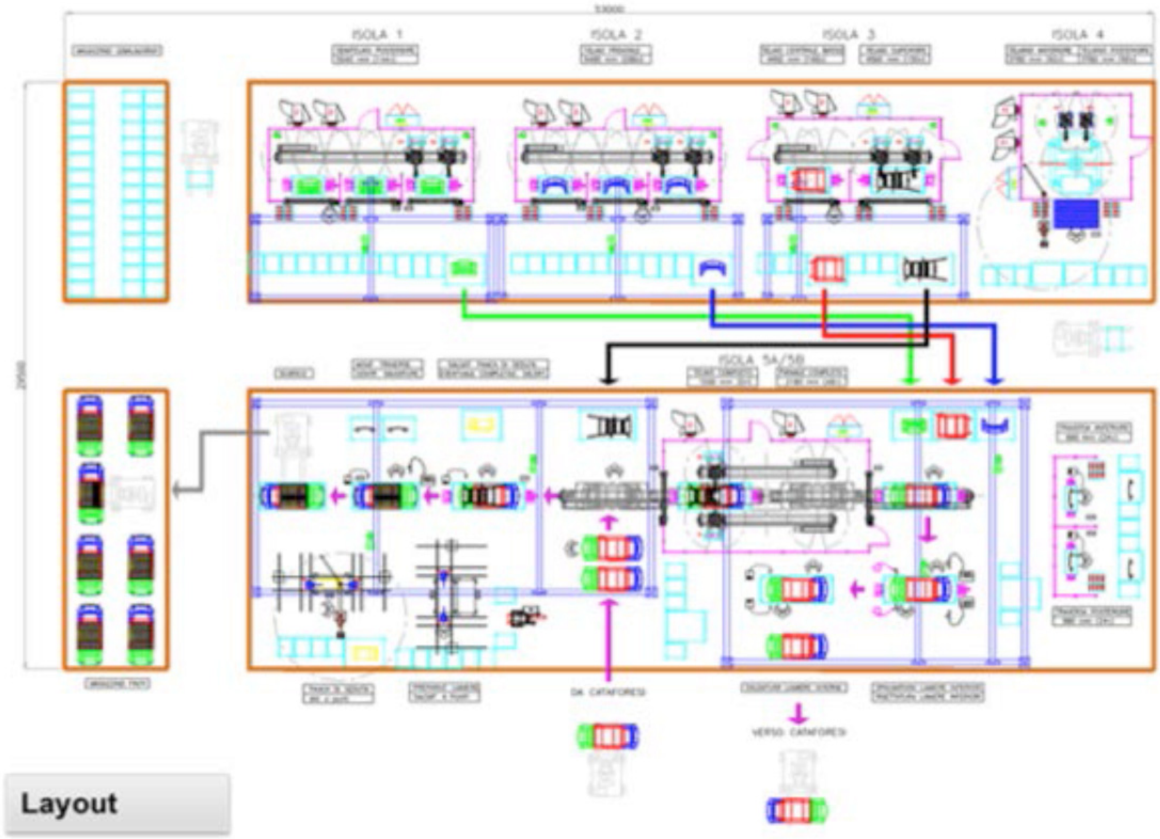

Figure 1. Layout of the assembly line

Organizational context

T2.1.2 ORGANIZATIONAL CONTEXT (5)		
Pilot case:	E-District(I-FEVS/POLIMODEL)	
Plant : (1)	Rivoli	
Line/Department: (2)	MICRO ELECTRIC VEHICLES	
Personnel directly involved (3)		
Teamwork Operators do mainly work at their assigned workstation but they cooperate continuously because they work in a manual assembly line. High because within the current structure organized per low volume production characterized by high product mix each operator is supposed to perform several tasks in collaboration with others	Low	High
Skill variety All the operators are trained to do several operations or can operate different machines. High as mentioned above	Low	High
Task identity (the corresponds to a whole unit of work, visible contribution to the final product)	Low	High
Cycle time: the assembling line is conceived for a maximum output of 50 chassis a day over 2 shifts. The full potential of the assembly line will be demonstrated within this project.	Min__3	Max_16
Level of standardization (limit autonomy on how to perform a task)	Low	High
Feedback (workers receive feedback from process) The operator do both visual and dimensional inspection of the result.	Low	High
Workers participation to continuous improvement initiatives (double loop learning).The workers have a very good experience in the process and often they give suggestion to improve the whole process. The experience gained by the personnel currently involved in manual operations will be transferred to the automatization of each island.	Low	High

(5) Attachment – Production system document (not currently available .The quality of the welding process is judged by the quality inspector by pass/no pass criteria)

Flexibility needs

T2.1.3 FLEXIBILITY NEEDS	
Pilot case:	E-District(I-FEVS/POLIMODEL)
Plant :	Rivoli
Line/Department:	MICRO ELECTRIC VEHICLES

Main type of products/parts involved			
N.	Product/part	Description	Comments
			The chassis is conceived to allow the manufacturing of a large number of different architectures. Within PERFORM the assembling line will be demonstrated to quickly switch from two different architectures (passenger vehicle and delivery of goods)
1	Tubular Chassis	For passengers	
1	Tubular chassis	Delivery of goods	
1	Axle frame	Standardized for both configurations	

Flexibility needs				
Type of flexibility needed	Range n.	Heterogeneity	Mobility	Uniformity
Volume	5 to 50 a day	At least 2 different architectures		
Variety	1 to 2			
Process	12 islands	All different		
Material handling	3 types of steel			
Labour	3 types of	Welding,		

		specialization	robotics,software engineer		
Version	Date	Respondent		Validation	

Social needs

T2.1.3 SOCIAL NEEDS					
Pilot case:	E-District(I-FEVS/POLIMODEL)				
Plant :	Rivoli				
Line/Department:	MICRO ELECTRIC VEHICLES				
Social needs					
Type of social objectives					
i.e. health and safety	During the welding activity all the fumes are aspired. All the islands are organized to assure the highest conceivable safety for all the personnel				
i.e. workers' wellbeing					
i.e. workers involvement					
Version	Date	Respondent		Validation	

Performance indicators (see APPENDIX)

In the following tables, different perspectives are offered to identify the challenges and opportunities for the human role in the TO BE CPPS situation. Although some categories may appear redundant or overlapping, the proposed approach is meant to better stimulate the reflection and not all the

T2.1.D PERFORMANCE INDICATORS			
Pilot case:	E-District(I-FEVS/POLIMODEL)		
Plant :	Rivoli		
Line/Department:	MICRO ELECTRIC VEHICLES		
Labor Flexibility Performance indicators			
Indicator	Type	Suitable for benchmark	Suitable for target
within the current structure organized per low volume production characterized by high product mix each operator is supposed to perform several tasks requiring different competences.			

Challenges and opportunities for the human role TO BE

FACTORY LIFECYCLE			
PHASE	**CHALLENGES/ OPPORTUNITIES**	**IMPLIED HUMAN ROLES**	**REQUIREMENTS FOR CHANGES**
Planning and Engineering	High product mix ,variable rate production, variable demand manufacturing, manufacturing per which non-recurring engineering cost became a large portion of the overall product cost	Multy skilled work force is necessary to handle the required flexibility and agility in a viable manner.	Training personnel in the cyber physical systems
Building/adaptation (reconfiguration) existing process/product introduce novel process/product to another product/plant			
Ramp up			
Manufacturing			
Refurbishment /Dismantling			

CPPS STATE (MANUFTURING)			
	CHALLENGES/ OPPORTUNITIES	**IMPLIED HUMAN ROLES**	**REQUIREMENTS FOR CHANGES**
Testing, Set up, Processing, Failure, Maintenance	Insufficient IT related knowledge, outsourcing policy with a scarcity of resources in ICT, highly manual control structure, lack of human resources, lack of long term sustainable production practices for highly dynamic markets	Multy skilled workforce is necessary	Need of specific training on CPS platforms
Set up			
Processing			
Failure			
Maintenance			

TYPE OF ACTIVITY (inspired from ISA 95)				
		CHALLENGES/ OPPORTUNITIES	IMPLIED HUMAN ROLES	REQUIREMENTS FOR CHANGES
Manufacturing Op. Mgt. Plant production scheduling		To be discussed on following meetings		
	Production Op.Mgt.			
	Maintainance Op.Mgt.			
	Quality Op. Mgt.			
	Inventory Op. Mgt.			
Monitoring, supervisory control of production processes Inspecting Detect deviations Activate help chain Fill-in forms/reports				
Sensing and manipulating Operational tasks execution Change over Ensure workplace tidiness				

OTHER ACTIVITIES AND DECISION MAKING			
	CHALLENGES/ OPPORTUNITIES	IMPLIED HUMAN ROLES	REQUIREMENTS FOR CHANGES
Suggestions for continuous improvement			
Problem solving			
Training			

APPENDIX

Examples of indicators

Workers can perform a large number of tasks YES	Range number	4	10
Workers are responsible for more than one task YES	Range number	4	10
A large number of job classifications exist in the workforce YES	Range number	4	10
Workers are cross-trained to perform many different tasks	Range number	8	10
Workers possess many different skills YES	Range number	8	10
The tasks which workers perform are very similar to one another NO	Range heterogeneity	1	5
Workers perform a diverse set of tasks YES	Range heterogeneity	1	5
Workers can perform various types of tasks YES	Range heterogeneity	4	10
Workers can perform tasks which differ greatly from one another YES	Range heterogeneity	4	10
A short time delay occurs when workers are moved between different tasks YES	Range heterogeneity		
It is easy to move workers between different tasks YES	Range heterogeneity		
It is easy to move workers between different tasks YES	Range heterogeneity		
A small cost is incurred (in dollars) when workers are moved between different tasks NO	Range heterogeneity		
A small cost is incurred (in terms of lost productivity) when workers are moved	Range heterogeneity		

between different tasks YES			
Workers can move easily between different tasks NO	Range heterogeneity		
Workers are equally effective, in terms of quality, for all tasks NO	Uniformity		
Workers are equally efficient at all tasks NO	Uniformity		
Workers achieve similar performance levels for all tasks NO	Uniformity		
Worker choice does not affect the processing cost (in dollars) of a task YES	Uniformity		
Workers are equally reliable for all tasks YES	Uniformity		
Workers are equally effective, in terms of productivity, for all tasks NO	Uniformity		
Quality of Working Life Performance indicators (Kulipers et al. 2004)			
Indicator	Type	Suitable for benchmark	Suitable for target

Some Indicators as a reference

Sick leave	YES		
Worker satisfaction	NO		
Involvement	NO		
Version	Date	Respondent	Validation

B. GKN

Introduction

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- the characteristics of the industrial context with reference to the culture and organization of work;
- the needs for flexibility;
- the social needs (safety, wellbeing, etc.)
- the performances to be pursued in terms of flexibility and satisfaction of social needs
- the indicators to measure the above mentioned performances
- the challenges and opportunities for the human role originating from the implementation of CPPS.

The present document represents a first release of a framework that enables a representation of the different organizational settings, needs, challenges and opportunities in a common and comparable manner.

Scope and boundaries

The first step consists in the definition of the organizational scope and boundaries:

T2.1.1 SCOPE AND BOUNDARIES TEMPLATE	
Pilot case:	GKN
Plant : (1)	Trollhättan / Engine Systems

Line/Department: (2)	(The use case / future industrial solution can be placed in any of the production departments)		
Personnel directly involved (3)			
N.	Role	Role description	Organizational unit
1	Supervisor / Production mgr.	1:st line manager with the traditional related tasks to recruit the right amout of personel with required competence, long term planning, safety & healt etc. Medium to short term production planning/scheduling is part of the role.	See attached ppt slides
x	oprators	Do all the value adding / processing for complete work cycles, which also includes making necessary documentation / administration.	See attached ppt slides
Personnel indirectly involved (4)			
N.	Role	Role description	Organizational unit
1	Quality engineer	Responsible for the inspection planning / follow up and supervises and handles any non conformances	See attached ppt slides
2	Maintenance	Similar to production	See attached ppt slides

	manager	mgr.	
3	Maintenance technicians	Inspection of equipment, service/maintenance and repairs.	See attached ppt slides
4	Product engineer	Responsible for the production preparations and process planning / instructions. Continuous Improvements etc.	
Version	Date	Respondent	Validation

(1) Attachment – map of the pant

(2) Attachment – layout of the line/department

(3) Attachment – organizational structure of the line/department

(4) Attachment – organizational structure encompassing all the units directly or indirectly involved.

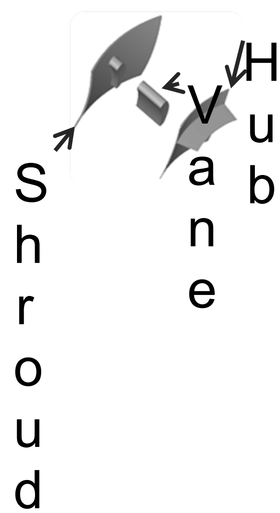
Organizational context

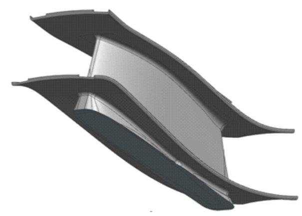
T2.1.2 ORGANIZATIONAL CONTEXT (5)		
Pilot case:		
Plant : (1)		
Line/Department: (2)		
Personnel directly involved (3)		
Teamwork Operators do mainly work at their assigned machine each shift and not directly in teams, but there are some exceptions. Each operator usually also have another task approx 10 – 20 % of the time. That could be to support planning, improvemtn work, tools management, support tests and tryouts, maintenemce ...	**Low**	High
Skill variety. Most operators knows / are trained to do several operations or can operate different machines. The training needed to do one job is usually quite long 1-3 months “on the job training” and under supervision by senior operators (not manager) who is qualified to train others. Given that the job is rather complex, requires long training and the operator has a large responsibility to inspect the reult of the work + the long cycle time – I would consider this to be High.	**Low**	High
Task identity (the corresponds to a whole unit of work, visible contribution to the final product)	Low	**High**

Yes, agree		
Cycle time (typical) There is a large variation, 1 h up to 10 is common, > 20 h are not unusual ... > 60 h exists	Min__**3h**_	Max__**8h**_
Level of standardization (limit autonomy on how to perform a task) Yes, agree	**<u>Low</u>**	High
Feedback (workers receive feedback from process) Well, the process and the equipment itself may not give much (direct / real time) feedback, but the operator do both visual and dimensional inspection, filling out protocols or input to SPC system, and also looking at the results. So, they do have a rather good view on how the process / machine is performing,	**<u>Low</u>**	High
Workers participation to continuous improvement initiatives (double loop learning) Yes and No. The operators are very skilled / well trained and often the ones that knows the process better than anyone else. Therfore they can provide many ideas for improvements (quality as well as efficiency). However they are not allowed to make any changes to process parameters or e.g. NC programs. That has to be done by an engineer. When improvements are implemented, the operator are involved in testing and verification etc.	**<u>Low</u>**	High

(5) Attechment – Production system document

Flexibility needs

T2.1.3 FLEXIBILITY NEEDS			
Pilot case:			
Plant :			
Line/Department:			
Some examples of planned parts for the use case and possible future applications			
Main type of products/parts involved			
N.	Product/part	Description	Comments
1	Vane	Guide vane - small parts that is used to build sub-assemblies for fabricated structural parts	
2	Hub segment	Part of a bearing hub - Small parts that is used to build sub-assemblies for fabricated structural parts	See above
3	Shroud segment	Part of an outer casing - Small parts that is used	See above

		to build sub-assemblies for fabricated structural parts	
4	Blades	Fan / Compressor Turbine blades	
5	Air duct	Part of e.g. an intermediate casing that is fabricated. Casted parts or with features made from AM	

Flexibility needs Im not sure how to fill this part. I have made some notes below. I hope that helps as a start.				
Type of flexibility needed	Range n.	Heterogeneity	Mobility	Uniformity
Volume This is the rage of volumes for the majority of products. The volume for each can vary +/- 20 to 50 % from year to year. (Market demand)	100 - 5000	?	?	?
Variety We have about 20 value streams in the work shops. Each (product type/family) have a few variants. In total				

there is about 100 different part numbers made.				
Process The processing equipment can usually make many different jobs. It is more of general type of equipment for machining, etc. (very few are dedicated for specific jobs). The tooling and fixtures need to be changed for diffeternt operations/products. Typical change over time is 20 – 60 minutes. Usually 3-6 different jobs are processed in each machine.				
Material handling Almost all material handling is manual / with lifting aids. Very flexible ? (Not automated)				
Labour Has some flexibility … see appendix for more information about operator flexibility.				

Version	Date	Respondent	Validation

Social needs

T2.1.3 SOCIAL NEEDS				
Pilot case:				
Plant :				
Line/Department:				
From score card / dash board …				
Social needs				
Type of social objectives	.			
Safety / Incidents	Frequency rate/year	[#/1000 employees]		
Safety / Lost work days		[# Days]		
Employee Survey / PCI (Positive Climate Index)	An index for 16 questions / areas to evaluate work satisfaction	The employees answer to the questions on a scale 1-4		
Version	Date	Respondent		Validation

Performance indicators (see APPENDIX)

In the following tables, different perspectives are offered to identify the challenges and opportunities for the human role in the TO BE CPPS situation. Although some categories may appear redundant or overlapping, the proposed approach is meant to better stimulate the reflection and not all the

T2.1.D PERFORMANCE INDICATORS			
Pilot case:			
Plant :			
Line/Department:			
See Appendix … OK?			
Labor Flexibility Performance indicators			
Indicator	Type	Suitable for benchmark	Suitable for target

Challenges and opportunities for the human role TO BE

FACTORY LIFECYCLE			
PHASE	**CHALLENGES/ OPPORTUNITIES**	**IMPLIED HUMAN ROLES**	**REQUIREMENTS FOR CHANGES**
Planning and Engineering	Need to change approach for the automation control system, to allow / enable the reconfigurable concept	Several roles within Production development and Operations. Managers as well as Manufacturing Engineers. (see different roles/departments on org chart)	Must have a mindset that flexibility / reconfigurability is an asset and not an extra cost – for relevant situations. Long term strategy / planning Business case calculation …
Building/adaptation (reconfiguration) ➔ existing process/product ➔ introduce novel process/product ➔ to another product/plant	The "micro flow cell" should have all these three opportunities, but what makes it different / unique is the ability to change/introduce a new process, or be moved.	People involved in industrialization (Different engineers + purchasing)	Must develop and adopt an architecture (and standard) to allow reconfiguration and step by step development. Must not make unique solutions that are not compatible.
Ramp up	Can be done faster …	Manufacturing Engineering Maintenance Operators	See above …
Manufacturing	Reduce cost, increase equipment utilization, production lead time … trough the flexibility/reconf.	Logistics / Production planning Maintenance Operators/Supervisors	Lear to use this as an advantage …/ enabler for efficiency.
Refurbishment /Dismantling	The goal is to more easily reuse equipment in other cells / applications	Maintenance	See above …

CPPS STATE (MANUFTURING)			
	CHALLENGES/ OPPORTUNITIES	**IMPLIED HUMAN ROLES**	**REQUIREMENTS FOR CHANGES**
Testing	Self check / testing after re-builds / change overs. Calibration / condition test of equipment	Equipment / Automation Engineering Maintenance	Design and build necessary features and functions into the system. (Can be especially important for safety system).
Set up	Much faster … and provide higher flexibility opportunities.	Production planning / scheduling Operator	(Planning / scheduling methods/system) Competence / Flex-training of operators
Processing	(Same …) Or higher level of automation Higher veriety of products / operations	Operators	Competence / Flex-training of operators. Instructions / Support from HMI
Failure	Product defects – no planned difference. Production equipment - Can resolve problems / replace equipment faster. Higher up-time.	N/A Operator / Maintenance instructions and training	NA Competence in automation systems + keep to the “standard” architecture etc. (don’t build unique solutions in each cell / process application)
Maintenance	Autonomous / preventive – no difference. Breakdown - Can resolve problems / replace equipment faster.	Maintenance engineering (planning) and execution.	Same as above.

TYPE OF ACTIVITY (inspired from ISA 95)				
		CHALLENGES/ OPPORTUNITIES	**IMPLIED HUMAN ROLES**	**REQUIREMENTS FOR CHANGES**
Manufacturing Op. Mgt. Plant production scheduling		Reconfigurability and flexibility as an advantage and enabler to adapt to changes in production demands and step by step automation	Managers / Exec. Management Team	Include in (long term) strategy and industrialisation plan Business case / investment calculation models.
	Production Op.Mgt.	Same / Similar as above	Managers / Op. Management Team	Principles and methods for long term capacity & industrial planning.
	Maintainance Op.Mgt.	Adapt its competence, planning and readiness to support higher level / system automation	M Managers and Engineers	Plan and adopt to required technologies, Competence …
	Quality Op. Mgt.	Automation / in-process inspection can provide more information and source inspection (more pro-active / less reactive)	Q Managers and Engineers	Q system methods and tools. Competence …
	Inventory Op. Mgt.	Less inventory / Shorter lead time	L Managers and Lead Planners	Principles and methods for planning & scheduling
Monitoring, supervisory control of production processes Inspecting Detect deviations Activate help chain Fill-in forms/reports		Automated processes and inspection / control provide new opportunities for in-line monitoring/ inspection and collect data (functions for information/data management can be included) Monitoring can detect problems / deviations and stop the process and activate alarms etc.	Process Engineers, Quality, Maintenance / Engineers.	Competences … Quality / Inspection methods to make use of the technology and all data. Automation technology

Sensing and manipulating Operational tasks execution Change over Ensure workplace tidiness	Can use small buffers and automated material handling in a cell for un-manned production.	Process Engineers, Quality, Maintenance / Engineers.	Competences … System design and programming

OTHER ACTIVITIES AND DECISION MAKING			
	CHALLENGES/ OPPORTUNITIES	**IMPLIED HUMAN ROLES**	**REQUIREMENTS FOR CHANGES**
Suggestions for continuous improvement	Use same / similar approach as today		
Problem solving	Use same / similar approach as today (other kind of problems may occur)		
Training	New competences / skills needed for higher level of automation etc.	Operators and technicians / engineers	Identify and plan for relevant training / knowledge transfer.

APPENDIX

Examples of indicators

I have appended a "Skill matrix" which shows how we plan and grade skills for differt tasks / jobs

Kompetensmatris.xlsx

Workers can perform a large number of tasks Yes, some	Range number Typical 4 -10		
Workers are responsible for more than one task Yes, usually	Range number See above		
A large number of job classifications exist in the workforce Not sure what you would consider many ...	Range number 5-10 including supplementary tasks		
Workers are cross-trained to perform many different tasks To some extent, yes	Range number See above		
Workers possess many different skills Yes, I would say so – lets discuss	Range number		
The tasks which workers perform are very similar to one another	Range heterogeneity		

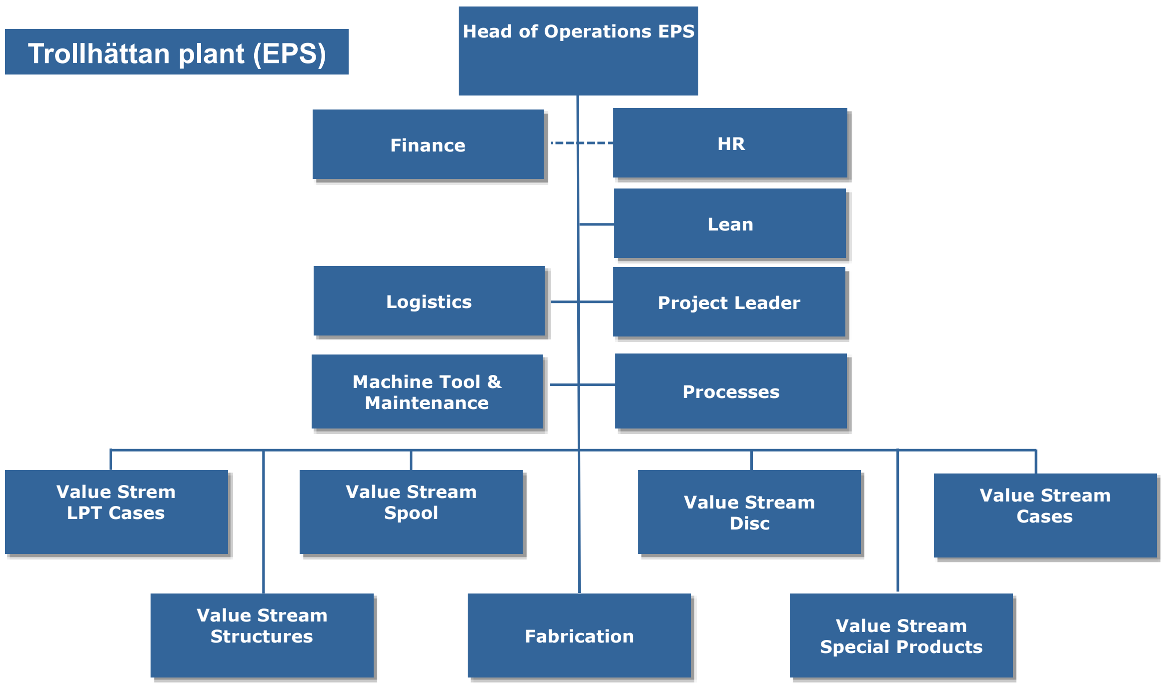
Yes / No – they do perform the same kind of tasks, but different jobs requires certain training and knowledge about the product/operations to be done and the machines/equipment.			
Workers perform a diverse set of tasks Yes / No – not all do that every day but the work is quite complex and includes different tasks during the week.	Range heterogeneity		
Workers can perform various types of tasks Yes / No – depends on their training (skills matix)	Range heterogeneity		
Workers can perform tasks which differ greatly from one another Yes / No – depends on their training (skills matix)	Range heterogeneity		
A short time delay occurs when workers are moved between different tasks No, not particularly in the ordinary work, but yes if they move from one team / department to another	Range heterogeneity		
It is easy to move workers between different tasks Yes / No – lets discuss	Range heterogeneity		

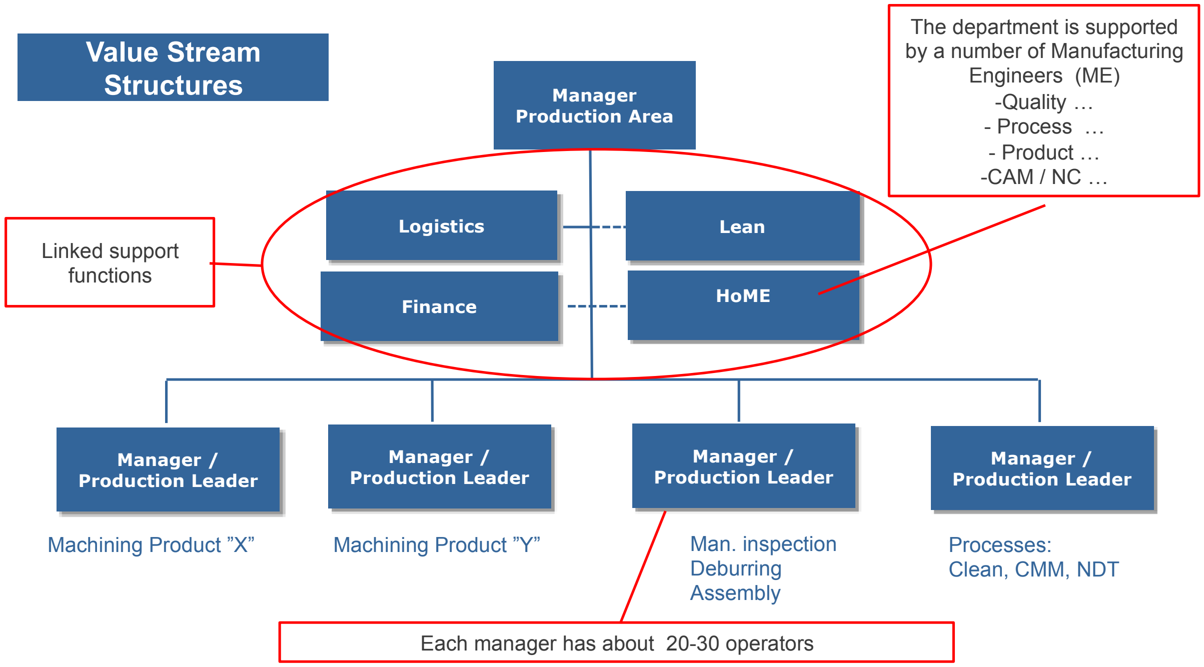
It is easy to move workers between different tasks Yes / No – easy for jobs they are already trained on, but new tasks requires training (sometimes months …)	Range heterogeneity		
A small cost is incurred (in dollars) when workers are moved between different tasks No	Range heterogeneity		
A small cost is incurred (in terms of lost productivity) when workers are moved between different tasks Yes	Range heterogeneity		
Workers can move easily between different tasks Yes, some, … but others requires more or less training	Range heterogeneity		
Workers are equally effective, in terms of quality, for all tasks No – some difference (experience / training etc...)	Uniformity		
Workers are equally efficient at all tasks No – some difference (experience / training etc...)	Uniformity		
Workers achieve similar	Uniformity		

performance levels for all tasks No – some difference (experience / training etc...)			
Worker choice does not affect the processing cost (in dollars) of a task Yes – some effect	Uniformity		
Workers are equally reliable for all tasks Yes / No – some are more well trained/experienced and there are levels of who can do what without supervision. There are also some tasks / operations that requires specific certification.	Uniformity		
Workers are equally effective, in terms of productivity, for all tasks No – some difference (experience / training etc...)	Uniformity		
Quality of Working Life Performance indicators (Kulipers et al. 2004)			
Indicator	Type	Suitable for benchmark	Suitable for target
See below			

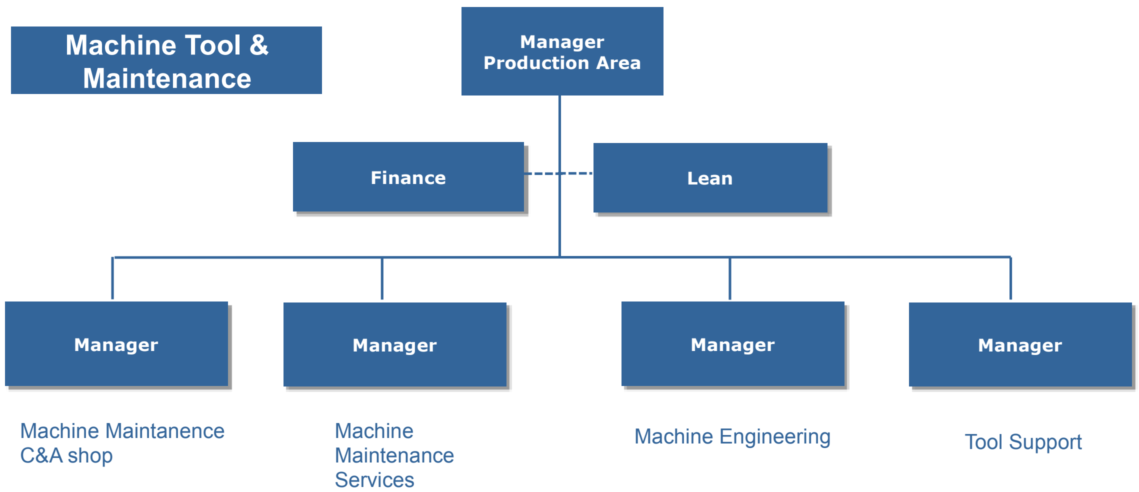
Some Indicators as a reference

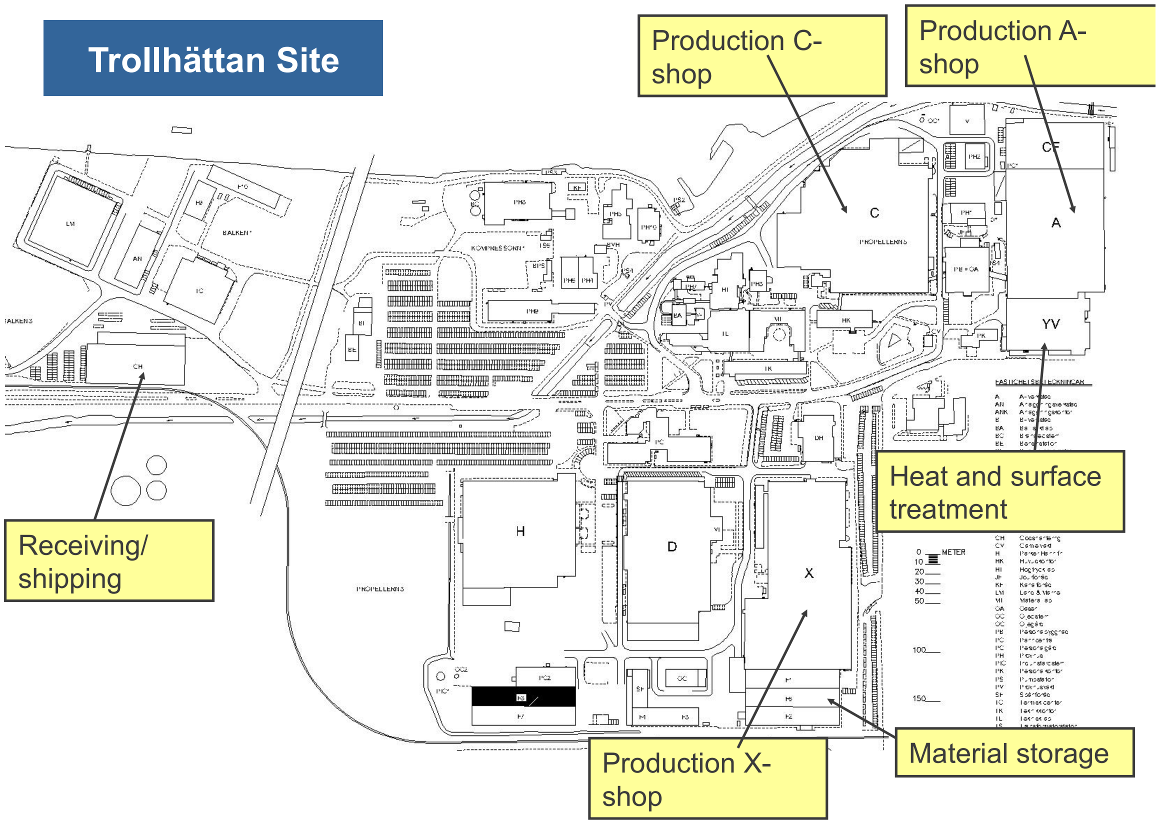
Sick leave	% absenteeism / total work force (or per category of employees)		
Worker satisfaction	Measured ...using the "PCI"	See section above	
Involvement …	Not in numbers, but discussed individually for each person by annual performance evaluation with manager		
Version	Date	Respondent	Validation

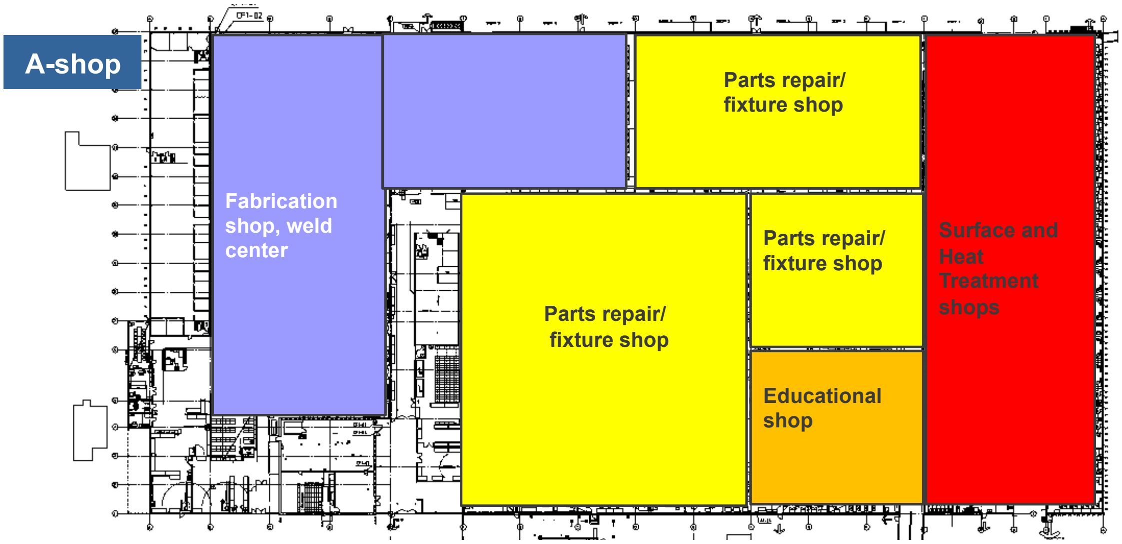

Trollhättan plant (EPS)
Head of Operations EPS
Finance
HR
Lean
Logistics
Project Leader
Machine Tool & Maintenance
Processes
Value Strem LPT Cases
Value Stream Spool
Value Stream Disc
Value Stream Cases
Value Stream Structures
Fabrication
Value Stream Special Products

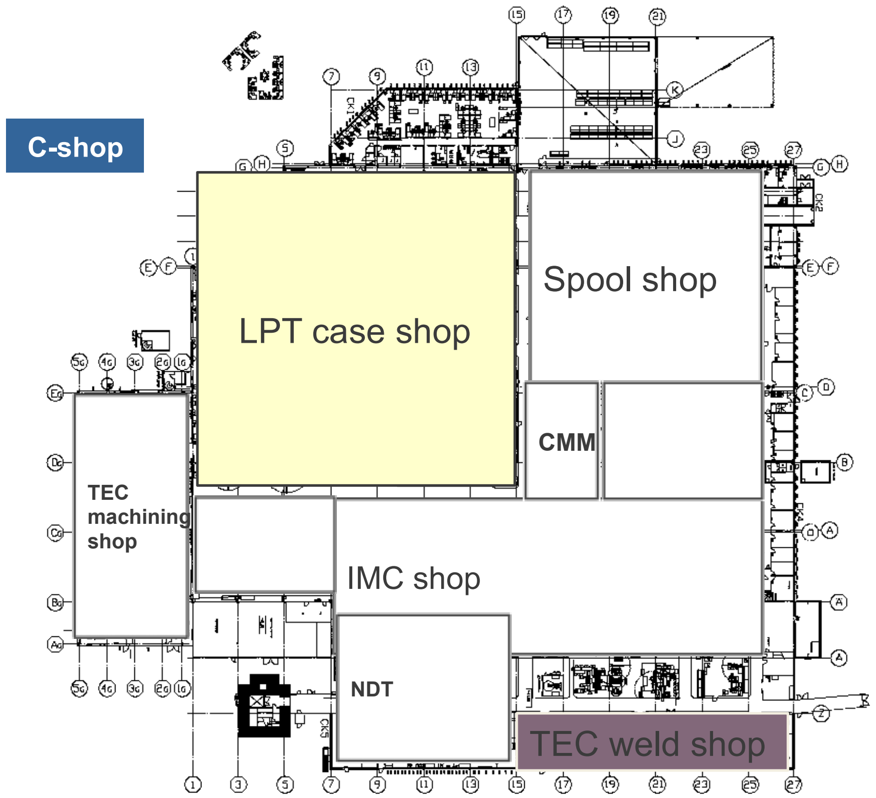

Value Stream Structures
Manager Production Area
The department is supported by a number of Manufacturing Engineers (ME)
-Quality …
- Process …
- Product …
-CAM / NC …
Linked support functions
Logistics
Lean
Finance
HoME
Manager / Production Leader
Manager / Production Leader
Manager / Production Leader
Manager / Production Leader
Machining Product "X"
Machining Product "Y"
Man. inspection
Deburring
Assembly
Processes:
Clean, CMM, NDT
Each manager has about 20-30 operators

valid from


Machine Tool & Maintenance
Manager Production Area
Finance
Lean
Manager
Manager
Manager
Manager
Machine Maintanence C&A shop
Machine Maintenance Services
Machine Engineering
Tool Support


Trollhättan Site
Production C-shop
Production A-shop
C
A
CF
YV
H
D
X
CH
Receiving/shipping
Heat and surface treatment
Production X-shop
Material storage


A-shop
Fabrication shop, weld center
Parts repair/ fixture shop
Parts repair/ fixture shop
Parts repair/ fixture shop
Educational shop
Surface and Heat Treatment shops


C-shop
LPT case shop
Spool shop
CMM
TEC
machining
shop
IMC shop
NDT
TEC weld shop

C. SIEMENS

Template to collect
organizational needs, challenges and opportunities

Introduction

The present template aims at collecting information from the Use Cases, relevant to the purposes of Task 2.1, that is developing Guidelines for seamless integration of Humans as flexibility driver in flexible production systems.

The document is meant to complement the description of the Use Case and the template for the collection of the industrial requirements developed in T1.1 and T1.2 with a special focus on organizational and human aspects.

The template is structured in order to capture:

the scope and boundaries of the use case with reference to the employees directly and indirectly involved;

the characteristics of the industrial context with reference to the culture and organization of work;

the needs for flexibility;

the social needs (safety, wellbeing, etc.)

the performances to be pursued in terms of flexibility and satisfaction of social needs

the indicators to measure the above mentioned performances

the challenges and opportunities for the human role originating from the implementation of CPPS.

The present document represents a first release of a framework that enables a representation of the different organizational settings, needs, challenges and opportunities in a common and comparable manner.

Scope and boundaries

The first step consists in the definition of the organizational scope and boundaries:

T2.1.1 SCOPE AND BOUNDARIES TEMPLATE	
Pilot case:	Siemens
Plant : (1)	Duisburg
Line/Department:	Manufacturing Department

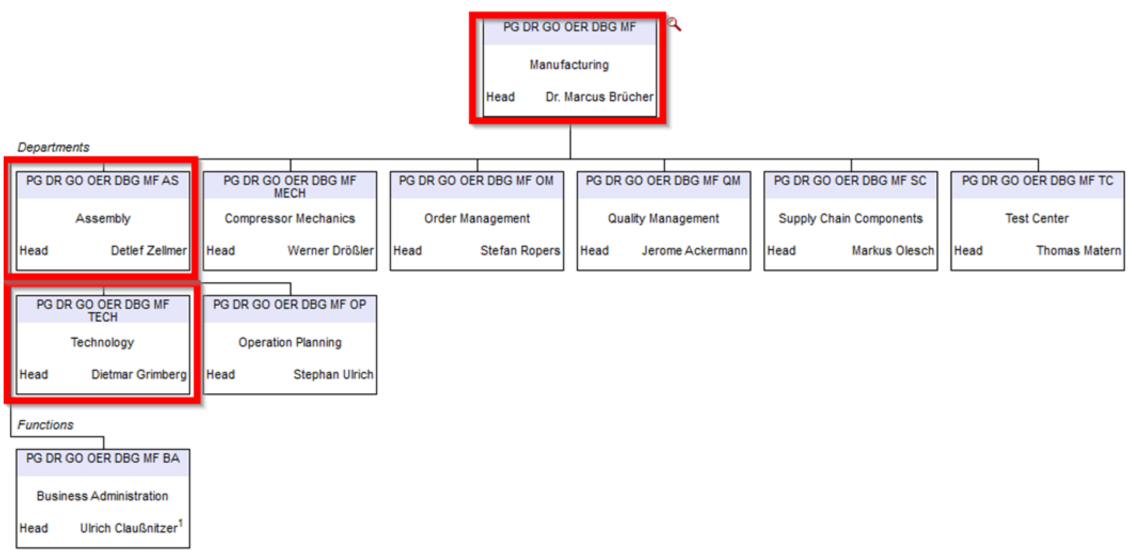
(2)			
Personnel directly involved (3)			
N.	Role	Role description	Organizational unit
1	Technology solutions lead	Responsible for factory technology solutions (robots and machinery)	PG DR GO OER DBG MF TECH 1
2	IT lead	Responsible for manufacturing IT	PG DR GO OER DBG MF TECH 4
3	Maintenance lead	Responsible for maintenance in the whole plant incl. all assets (excl. some IT)	PG DR GO OER DBG MF TECH 5
4	xxx employee	Employees of the respective departments (e.g. maintenance personal)	
Personnel indirectly involved (4)			
N.	Role	Role description	Organizational unit
1	Manufacturing manager	Responsible for all operations / business that relates to the Manufacturing of products (e.g. Assembly, Product engineering, quality management, supply chain, test center, manufacturing, operation planning, business administration	PG DR GO OER DBG MF
2	Plant manager	Responsible for the overall business of the plant incl. Manufacturing, Improvement projects, Environmental protection, Health management and Safety, Project Engineering and Project Management	PG DR GO OER DBG
4	Assemby Management	Responsible for Shopfloor manufacturing and all plant operator personal	PG DR GO OER DBG MF AS
Version	Date	Respondent	Validation
1	21.01.2016	Matthias Foehr	

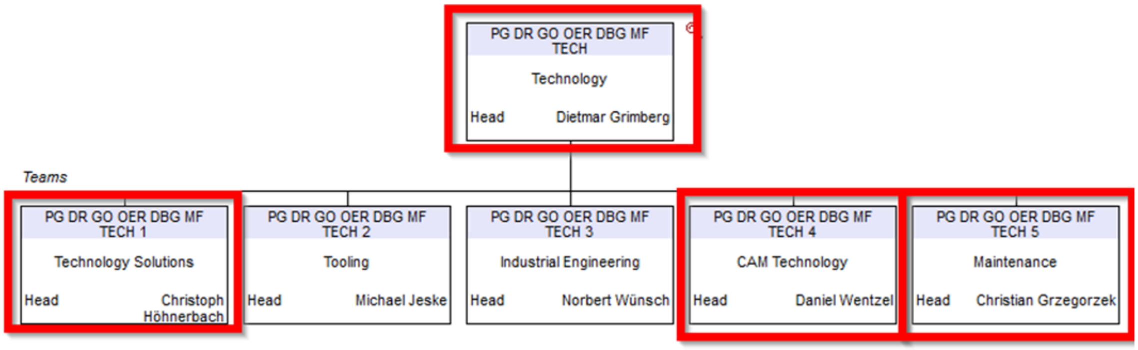
Attachment – map of the pant

Attachment – layout of the line/department

Attachment – organizational structure of the line/department

Attachment – organizational structure encompassing all the units directly or indirectly involved.





Organizational structures

Organizational context

T2.1.2 ORGANIZATIONAL CONTEXT (5)			
Pilot case:	Siemens		
Plant : (1)	Duisburg		
Line/Department: (2)	Manufacturing		
Personnel directly involved (3)			
Teamwork		Low	High
Skill variety		Low	High
Task identity (the corresponds to a whole unit of work, visible contribution to the final product)		Low (Maintenance)	High (Technology solutions)
Cycle time		Min 4h	Max 5 days
Level of standardization (limit autonomy on how to perform a task)		Low	High
Feedback (workers receive feedback from process)		Low	High
Workers participation to continuous improvement initiatives (double loop learning)		Low (individually)	High (individually)

(5) Attachment – Production system document

Flexibility needs

T2.1.3 FLEXIBILITY NEEDS			
Pilot case:	Siemens		
Plant :	Duisburg		
Line/Department:	Manufacturing		
Main type of products/parts involved			
N.	Product/part	Description	Comments
1	Whole Line	As Lotsize in the Dusiburg plant is 1,4 (medium) the whole line needs to be very flexible in order to cope with varying products	
2	Maintenance system	The maintenance is one of the key enablers for flexibility on the production line. Depending on the type of maintenance (planned, unplanned, immediate, foreseen) the maintenance personal needs to be able to flexibly adapt to these tasks. E.g. a planned maintenance might be postpone in order to guarantee timely delivery of an already delayed component. Otherwise a breakdown needs to be maintained immediately including dynamical replanning of the production process	
3	Scheduling	The scheduling system is the central planning instrument for all orders. It's flexibility needs to be	

		increased in order to react to maintenance tasks, taking into consideration the actual orders, the availability of machines, the likelyhood of (near) future machine breakdowns, planned maintenance tasks, actual order status (e.g. delayed) etc.	

Flexibility needs				
Type of flexibility needed	Range n.	Heterogeneity	Mobility	Uniformity
Volume	1	High	Low (parts are quite heavy)	Low
Variety	>100			
Process				
Material handling				
Labour				

Version	Date	Respondent	Validation

Social needs

T2.1.3 SOCIAL NEEDS				
Pilot case:	Siemens			
Plant :	Duisburg			
Line/Department:	Manufacturing			
Social needs				
Type of social objectives				
i.e. health and safety				
i.e. workers' wellbeing				
i.e. workers involvement				
Version	Date	Respondent		Validation

Performance indicators (see APPENDIX)

In the following tables, different perspectives are offered to identify the challenges and opportunities for the human role in the TO BE CPPS situation. Although some categories may appear redundant or overlapping, the proposed approach is meant to better stimulate the reflection and not all the

T2.1.D PERFORMANCE INDIC2ATORS			
Pilot case:	Siemens		
Plant :	Duisburg		
Line/Department:	Manufacturing		
Labor Flexibility Performance indicators			
Indicator	Type	Suitable for benchmark	Suitable for target
See appendix			

Challenges and opportunities for the human role TO BE

FACTORY LIFECYCLE			
PHASE	**CHALLENGES/ OPPORTUNITIES**	**IMPLIED HUMAN ROLES**	**REQUIREMENTS FOR CHANGES**
Planning and Engineering			
Building/adaptation (reconfiguration) existing process/product introduce novel process/product to another product/plant			
Ramp up			
Manufacturing	React to sudden breakdown / proactively prevent breakdowns	Operators, maintenance personal, scheduler	Integration of scheduling, ordering, equipment monitoring and maintenance tools on one platform.
Refurbishment /Dismantling			

CPPS STATE (MANUFTURING)			
	CHALLENGES/ OPPORTUNITIES	**IMPLIED HUMAN ROLES**	**REQUIREMENTS FOR CHANGES**
Testing			
Set up			
Processing	Identification of inadequate system/process behavior	Operatior, maintenance	Evaluation of existing and prospective data (sensor, plc, …) of processes / machines
Failure			
Maintenance	Proactively planned maintenance	Maintenance, scheduler	Integration of scheduling, ordering, equipment monitoring and maintenance tools on one platform.

TYPE OF ACTIVITY (inspired from ISA 95)				
		CHALLENGES/ OPPORTUNITIES	**IMPLIED HUMAN ROLES**	**REQUIREMENTS FOR CHANGES**
Manufacturing Op. Mgt. Plant production scheduling				
	Production Op.Mgt.			
	Maintainance Op.Mgt.			
	Quality Op. Mgt.			
	Inventory Op. Mgt.			
Monitoring, supervisory control of production processes Inspecting Detect deviations Activate help chain Fill-in forms/reports				
Sensing and manipulating Operational tasks execution Change over Ensure workplace tidiness				

OTHER ACTIVITIES AND DECISION MAKING			
	CHALLENGES/ OPPORTUNITIES	**IMPLIED HUMAN ROLES**	**REQUIREMENTS FOR CHANGES**
Suggestions for continuous improvement			
Problem solving			
Training			

APPENDIX

Examples of indicators

Workers can perform a large number of tasks	Range number	>5	
Workers are responsible for more than one task	Range number	1-3	
A large number of job classifications exist in the workforce	Range number	<10	
Workers are cross-trained to perform many different tasks	Range number	Limited	
Workers possess many different skills	Range number	No	
The tasks which workers perform are very similar to one another	Range heterogeneity	<5	
Workers perform a diverse set of tasks	Range heterogeneity	<5	
Workers can perform various types of tasks	Range heterogeneity	<5	
Workers can perform tasks which differ greatly from one another	Range heterogeneity	<3	
A short time delay occurs when workers are moved between different tasks	Range heterogeneity	No	
It is easy to move workers between different tasks	Range heterogeneity	Yes	
It is easy to move workers between different tasks	Range heterogeneity		
A small cost is incurred (in dollars) when workers are moved between different tasks	Range heterogeneity	Yes	
A small cost is incurred (in terms of lost productivity) when workers are moved between different tasks	Range heterogeneity	Yes	
Workers can move easily between different tasks	Range heterogeneity	No	
Workers are equally	Uniformity	No	

effective, in terms of quality, for all tasks			
Workers are equally efficient at all tasks	Uniformity	No	
Workers achieve similar performance levels for all tasks	Uniformity	No	
Worker choice does not affect the processing cost (in dollars) of a task	Uniformity	Yes	
Workers are equally reliable for all tasks	Uniformity	No	
Workers are equally effective, in terms of productivity, for all tasks	Uniformity	No	
Quality of Working Life Performance indicators (Kulipers et al. 2004)			
Indicator	Type	Suitable for benchmark	Suitable for target

Some Indicators as a reference

Sick leave			
Worker satisfaction			
Involvement			
Version	Date	Respondent	Validation

D. WHIRLPOOL

Production harmonizEd Reconfiguration of Flexible Robots and Machinery

Horizon 2020 – Factories of the Future, Project ID: 680435

Template to collect organizational needs, challenges and opportunities

T2.1 Guidelines for seamless integration of Humans as flexibility driver in flexible production systems

Lead Author: POLIMI

Version: 01
Date: 22.12.2015
Status: release 0.3

7 Summary

1. INTRODUCTION 54
2. SCOPE AND BOUNDARIES 54
3. ORGANIZATIONAL CONTEXT 57
4. FLEXIBILITY NEEDS 58
5. SOCIAL NEEDS 60
6. PERFORMANCE INDICATORS (SEE APPENDIX) 61
7. CHALLENGES AND OPPORTUNITIES FOR THE HUMAN ROLE TO BE 62
A. APPENDIX 66

1. INTRODUCTION 7
1.1. OBJECTIVES AND SCOPE 7
1.2. INTEGRATION WITHIN THE PROJECT ACTIVITIES 7
1.3. STRUCTURE OF THE DOCUMENT 7
2. METHODOLOGICAL APPROACH 8
3. PRODUCTION SYSTEMS CHARACTERIZATION 9
3.1. PRODUCTION SYSTEMS, PHASES AND STATES 9
3.2. PRODUCTION ACTIVITIES AND ROLES 11
3.1.1 Production activities and roles 11
3.1.2 Maintenance Management & Scheduling 15
3.3. SOCIO-TECHNICAL SYSTEMS AND LEAN PRODUCTION SYSTEMS 18
3.4. FLEXIBILITY PERFORMANCES IN PRODUCTION 19
3.5. SOCIAL/HUMAN PERFORMANCES IN PRODUCTION 20
4 ORGANIZATIONAL FRAMEWORK AND ANALYSIS OF REQUIREMENTS, CHALLENGES AND OPPORTUNITIES FOR EACH USE CASE 21
4.1 I-FEVS 21
4.1.1 Production System 21
4.1.2 "AS IS" 22
4.1.3 "TO BE" 23
4.1.4 Highlights 25
4.2 GKN 25
4.2.1 Production system 25
4.2.2 "AS IS" 26
4.2.3 "TO BE" 26
4.2.4 Highlights 27
4.3 SIEMENS 28
4.3.1 Production system 28
4.3.2 "AS IS" 30

4.3.3 "TO BE" ... 31
4.3.4 Highlights ... 34
4.4 WHIRLPOOL (WHIRLPOOL) ... 35
4.4.1 Production system ... 35
4.4.2 "AS IS" ... 35
4.4.3 "TO BE" ... 35
4.4.4 Highlights ... 36

5 GAP ANALYSIS AND RECOMMENDATIONS ... 36

5.1 GAP ANALYSIS ... 36
5.2 RECOMMENDATIONS ... 40
5.2.1 Human-in-the-Loop Recommendations ... 41
5.2.2 Human-in-the-Mesh Recommendations ... 42

6 CONCLUSIONS AND OUTLOOK ... 42

I. APPENEDIX – SOCIAL PERFORMANCE INDICATORS (SO SMART PROJECT) ... 44

II. APPENDIX – QUESTIONNAIRES GATHERED FROM THE USE CASES ... 50

A. I-FEVS ... 51
B. GKN ... 68
C. SIEMENS ... 95
D. WHIRLPOOL ... 113

III. APPENDIX - ANALYSIS OF SELECTED SCENARIOS WITHIN THE USE CASES ... 129

A. I-FEVS ... 130
B. GKN ... 134
C. SIEMENS ... 138
D. WHIRLPOOL ... 147

Introduction

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the characteristics of the industrial context with reference to the culture and organization of work;

the needs for flexibility;

the social needs (safety, wellbeing, etc.)

the performances to be pursued in terms of flexibility and satisfaction of social needs

the indicators to measure the above mentioned performances

the challenges and opportunities for the human role originating from the implementation of CPPS.

The present document represents a first release of a framework that enables a representation of the different organizational settings, needs, challenges and opportunities in a common and comparable manner.

Scope and boundaries

The first step consists in the definition of the organizational scope and boundaries:

T2.1.1 SCOPE AND BOUNDARIES TEMPLATE	
Pilot case:	WHR
Plant : (1)	Microwave Oven Cassinetta
Line/Department:	Entire Value Stream Primary Process + assembly line

(2)			
Personnel directly involved (3)			
N.	Role	Role description	Organizational unit
30	Equipment assistant	Supervise equipment, load and unload parts	Primary Processes
150	Assembly operator	Assemble parts and test product on continuous assembly line	Assembly
Personnel indirectly involved (4)			
N.	Role	Role description	Organizational unit
2	Production Team Leaders	Coordinate team of Equipment Assistant belonging to a specific deparment	Primary Processes
8	Production Team Leaders	Coordinate team of Assembly Operators belonging to a specific line	Assembly
14	Quality Specialist	Ensure manufacturing Quality through test and measurement of parts and process	Quality
32	Material handling/ware house team member	Supply material to assembly line and manage component warehouse	Material Management
8	Material handling/ware house team leaders	Coordinate team of Material handling/warehouse team member	Material Management
2	Maintenance Operator	Maintain equipments (preventive, predictive, ordinary)	Maintenance
5	Group Leader	Lead Groups (Primary Process, Assembly Line workers, Maintenance and Quality)	Production, Quality, Maintenance
1	Value Stream Manager	Manage all Microwave Oven value stream	Production
Version	Date	Respondent	Validation
1.0	21.1.2016		

Attachment – map of the plant

Attachment – layout of the line/department

Attachment – organizational structure of the line/department

Attachment – organizational structure encompassing all the units directly or indirectly involved.

Organizational context

T2.1.2 ORGANIZATIONAL CONTEXT (5)		
Pilot case:	WHR	
Plant : (1)	Microwave Oven Cassinetta	
Line/Department: (2)	Entire Value Stream Primary Process + assembly line	
Personnel directly involved (3)		
Teamwork	Low	High
Skill variety	Low	High
Task identity (the corresponds to a whole unit of work, visible contribution to the final product)	Low	High
Cycle time	Min_50___	Max_50__
Level of standardization (limit autonomy on how to perform a task)	Low	High
Feedback (workers receive feedback from process)	Low	High
Workers participation to continuous improvement initiatives (double loop learning)	Low	High

(5) Attachment – Production system document

Flexibility needs

T2.1.3 FLEXIBILITY NEEDS					
Pilot case:	WHR				
Plant :	Microwave Oven Cassinetta				
Line/Department:	Entire Value Stream Primary Process + assembly line				
Main type of products/parts involved					
N.	Product/part	Description		Comments	
#sku	Mini				
	MIDI				
	Opera				
	Phoenix				
Flexibility needs					
Type of flexibility needed		Range n.	Heterogeneity	Mobility	Uniformity
Volume					
Variety					
Process					
Material handling					
Labour					
Version	Date	Respondent		Validation	

Social needs

T2.1.3 SOCIAL NEEDS					
Pilot case:	WHR				
Plant :	Microwave Oven Cassinetta				
Line/Department:	Entire Value Stream Primary Process + assembly line				
Social needs					
Type of social objectives		Normative	Internal Policy	Social Responsibility	Organizational Driven
i.e. Environment, health and safety		Risk assessment, Accidents Prevention	Various activities to improve eh&s	Remediation, Pollution Avoidance, Material recycling	Special Campaign dedicated to illness prevention
i.e. workers' wellbeing		Local laws full respect	Engagement survey	CRAL, Blood donhor association, Medical center, Transportation Services, Canteen	Ergonomic workplace design
i.e. workers involvement				Recognition system in place (Turn-it-on, I-Improve)	Help Chain, Internal communication
Version	Date	Respondent		Validation	

Performance indicators (see APPENDIX)

In the following tables, different perspectives are offered to identify the challenges and opportunities for the human role in the TO BE CPPS situation. Although some categories may appear redundant or overlapping, the proposed approach is meant to better stimulate the reflection and not all the

T2.1.D PERFORMANCE INDICATORS			
Pilot case:	WHR		
Plant :	Microwave Oven Cassinetta		
Line/Department:	Entire Value Stream Primary Process + assembly line		
Labor Flexibility Performance indicators			
Indicator	Type	Suitable for benchmark	Suitable for target
Yearly Calendar Factory	Variable open / close according to market request	Y	Y
Daily PSA	Production Scheduling actualization	Y	Y
Weekly PSA	Production Scheduling actualization	Y	Y
Maintenance Worker weekly scheduling		Y	Y
OEE	Overall Equipment Efficiency	Y	Y

Challenges and opportunities for the human role TO BE

FACTORY LIFECYCLE			
PHASE	**CHALLENGES/ OPPORTUNITIES**	**IMPLIED HUMAN ROLES**	**REQUIREMENTS FOR CHANGES**
Planning and Engineering	Direct worker not involved in phase		
Building/adaptation (reconfiguration) existing process/product introduce novel process/product to another product/plant	Team Leader and Quality Specialists to transfer knowledge / experience to new / adapted line		
Ramp up	Training Within Industry full exploitation		
Manufacturing	Full application of Whirlpool Production System		
Refurbishment /Dismantling	Direct worker involved in refurbishment and dismantling		

CPPS STATE (MANUFTURING)			
	CHALLENGES/ OPPORTUNITIES	**IMPLIED HUMAN ROLES**	**REQUIREMENTS FOR CHANGES**
Testing			
Set up			
Processing			
Failure			
Maintenance			

TYPE OF ACTIVITY (inspired from ISA 95)				
		CHALLENGES/ OPPORTUNITIES	**IMPLIED HUMAN ROLES**	**REQUIREMENTS FOR CHANGES**
Manufacturing Op. Mgt. Plant production scheduling				
	Production Op.Mgt.			
	Maintainance Op.Mgt.			
	Quality Op. Mgt.			
	Inventory Op. Mgt.			
Monitoring, supervisory control of production processes Inspecting Detect deviations Activate help chain Fill-in forms/reports				
Sensing and manipulating Operational tasks execution Change over Ensure workplace tidiness				

OTHER ACTIVITIES AND DECISION MAKING			
	CHALLENGES/ OPPORTUNITIES	IMPLIED HUMAN ROLES	REQUIREMENTS FOR CHANGES
Suggestions for continuous improvement			
Problem solving			
Training			

APPENDIX

Examples of indicators

Workers can perform a large number of tasks	Range number		
Workers are responsible for more than one task	Range number		
A large number of job classifications exist in the workforce	Range number		
Workers are cross-trained to perform many different tasks	Range number		
Workers possess many different skills	Range number		
The tasks which workers perform are very similar to one another	Range heterogeneity		
Workers perform a diverse set of tasks	Range heterogeneity		
Workers can perform various types of tasks	Range heterogeneity		
Workers can perform tasks which differ greatly from one another	Range heterogeneity		
A short time delay occurs when workers are moved between different tasks	Range heterogeneity		
It is easy to move workers between different tasks	Range heterogeneity		
It is easy to move workers between different tasks	Range heterogeneity		
A small cost is incurred (in dollars) when workers are moved between different tasks	Range heterogeneity		
A small cost is incurred (in terms of lost productivity) when workers are moved between different tasks	Range heterogeneity		
Workers can move easily between different tasks	Range heterogeneity		
Workers are equally	Uniformity		

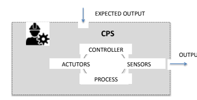
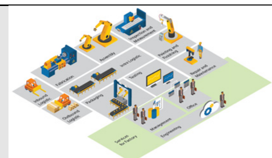
effective, in terms of quality, for all tasks			
Workers are equally efficient at all tasks	Uniformity		
Workers achieve similar performance levels for all tasks	Uniformity		
Worker choice does not affect the processing cost (in dollars) of a task	Uniformity		
Workers are equally reliable for all tasks	Uniformity		
Workers are equally effective, in terms of productivity, for all tasks	Uniformity		
Quality of Working Life Performance indicators (Kulipers et al. 2004)			
Indicator	Type	Suitable for benchmark	Suitable for target

Some Indicators as a reference

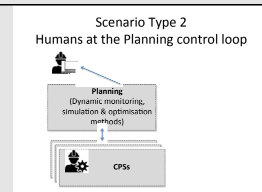
Sick leave			
Worker satisfaction			
Involvement			
Version	Date	Respondent	Validation

III. APPENDIX - ANALYSIS OF SELECTED SCENARIOS WITHIN THE USE CASES

A. I-FEVS

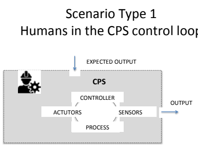
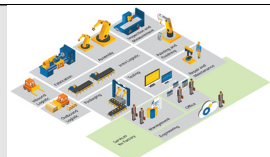
Scenario	**I-FEVS-ED/POL-ED**			
Type	**1**	Scenario Type 1 Humans in the CPS control loop 		
Scope/1-process view		**Fabrication** **Assembly** **Inspection & Measuring** **Painting and finishing** **Testing** **Packaging**	**Repair & Maint.** **Intra logistic** **Inbound logistic** **Outbound logistic** **Service for factory**	**Office** **Mgt** **Engineering**
Scope/2-Production system lifecycle phase	**Planning & Engineering** **Building and adaptation (reconfiguration)** **Ramp-up** **Production** **Refurbishment/Dismantling**	**Scope/3-Production states**	**Testing** **Set-up** **Processing** **Failure** **Maintenance**	
Involved human role(s)	**Operator in the assembly line**			
Human activities	**Short description**	**Potential impact of these activities on performanc e**	**Barriers and enablers to deploy the full potential of human role (skills, organization, methods, tools, etc.)**	**Preliminary recommendations**
Supervision and set-point adjustment	**Supervising the welding operations and adjustment of the set-point.**	**High (quality)**	**Welding skills Knowledge of the tools Robot set-up**	**Training on the MES user interface and welding**
			The worker does not have the knowledge of what is occurring…..	**Provide a mobile user interface connected with CPPS (tablet / smart phone/smart glasses)**
			The operator may mistake the … (sequence, dimension, tolerance…)	**Provide the operator alerts in case of mistake**
			The operator has no experience enough to	**Enable the operator to consult a colleague same/different unit**

			address	
Command the system (task execution)	**Commanding the robot operations (programming)**	**High**	**Robot interface**	**Training on the MES user interface**
Data provision	**identification, early detection, reporting of data**	**High (quality, efficiency)**	**CPS knowledge**	**Training on the MES user interface** **Tools for geometrical testing, power train testing and fatigue testing to support the operator**
Disturbance	**human error in quality check**	**High**	**Organization skills** **Methods**	**Teaching to do the quality test** **Experience in quality analysis**
Other				

Scenario	**I-FEVS-ED/POL-ED**			
Type	**2**			
Scope/1-process view		**Fabrication** **Assembly** **Inspection & Measuring** **Painting and finishing** **Testing** **Packaging**	**Repair & Maint.** **Intra logistic** **Inbound logistic** **Outbound logistic** **Service for factory**	**Office** **Mgt (HR)** **Engineering**
Scope/2-Production system lifecycle phase	**Planning & Engineering** **Building and adaptation (reconfiguration)** **Ramp-up** **Production** **Refurbishment/Dismantling**	**Scope/3-Production states**	**Testing** **Set-up** **Processing** **Failure** **Maintenance**	
Involved human role	**Supply Chain manager,**			
Human activities	**Short description**	**Potential impact of these activities on performance (KPIs)**	**Barriers and enablers to deploy the full potential of human role (skills, organization, methods, tools, etc.)**	**Preliminary recommendations**
Human identify situation and Intervenes (changes the system State/ expected output, activates other systems, etc.)	**Reconfigure the production system (and supply chain) to accommodate volume and type variances, Flexible production of different vehicles configuration**	**High**	**Authority to make decisions** **Knowledge of the process** **Interaction with the supply chain to adjust orders delivery.**	**Trained in decision making** **MES (rescheduling)** **Organization role design**
Human	**Change of the planning due**	**High**	**Organization**	**Experience in**

analyses and changes the planning	**to logistic problem or production demanding**		**skills**	**logistic and production**
Knowledge extraction form human observation				
Other				

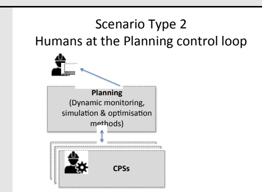
B. GKN

Scenario	GKN-1 (Scope/1 adapted to the GKN use case – Flexible/Reconfigurable Cell)			
Type	1 Focus on Scope 1/3, i.e operation of the cell	 		
Scope/1-process view	 The assets to the left are different one that will be used in different reconfigurations – not everything at all times	Material handling – in a production cell Machining – (with robots) grinding/polishing Inspection – dimensional measurements, surface finish Storage – in cell buffer / raw material, tools, etc Robots –deburring, tool handling, part handling Human – shop floor operators etc. many different tasks ... Marking – dot pen, vision/camera ...	Repair & Maint. Office Mgt Engineering	
Scope/2-Production system lifecycle phase	Planning & Engineering Building and adaptation (reconfiguration) Ramp-up Production Refurbishment/Dismantling	Scope/3-Production states	Testing Set-up Processing Failure Maintenance	
Involved human role(s)	Operators Process Engineer Maintenance			
Human activities	Short description	Potential impact of these activities on performanc e	Barriers and enablers to deploy the full potential of human role (skills, organization, methods, tools, etc.)	Preliminary recommendations
Supervision and set-point adjustment	Scope 1/3 The activities to prepare the work before process cycle start, i.e. set up fixture / tooling / parts, programs, parameters etc.	Down time / waiting – low utilisation (safety)	Flexibility training (skills/qualificat ion) to do the different kind of jobs in the cell. (Goal should be that one operator can attend one / several cell or work stations.	Skills / Job flexibility training needed. Training / Qualifications to operate robots / automation equipment in this kind of cells
Command the system (task	The goal is automated (robust/reliable) processing that should not require on-	Quality ... Process /Cycle time	Enabler – make use of operator skills/knowledg	Chose principles and solutions for: Signal /

execution)	**line monitoring/adjustments by the operator. Control of the (value adding) processing should be in the cell. However there can be some in-process monitoring / inspection that need actions/adjustments by operator.**	**losses Waiting …**	**e (which is very good) to do the process planning etc. for a good solution When the process is set/working – limit the possibility for (un wanted) human interventions Barrier – if the operators/engineers don't get the necessary signals and information to act in time**	**"Communication" concepts HMI design / functions Instructions / training**
Data provision	**Any kind of "data" (and information?) managed by the human before, during, after the operation cycle (Start to finish of each job)**	**Quality Waiting … … but also preventing errors/problems**	**The human with its 6 senses and, under right conditions, real time analytical capabilities is a very good asset to see and take actions. However, routine data management is safer and more efficient to automate. Also, for process monitoring and most inspection, "automation" is better (usually faster/more reliable.)**	**Visual inspection of parts and equipment should still be done, but complemented/ supported with sensors etc. Inspection routines, training and design/functions of HMI should be analysed and considered. In our case the different kind of processes in one cell may need different competence/ qualifications to make inspection on the product.**
Disturbance	**Any kind of disturbance caused by human due to errors/mistakes. Root causes can be lack of robustness in the design of the system, or process capabilities, lack of knowledge/training, confusing feed back/signal system, accidental safety stops etc.**	**Quality … Process /Cycle time losses Waiting … Safety**	**Reduce risks of human mistakes – conscious and well as unconscious.**	**Risk analysis in the design phase. Design functions features etc. with an "Error Proofing" mindset. Instructions / training plan.**
Other –	**Operator – Daily tasks …**	**Quality …**	**- With the right**	**Chose principles and**

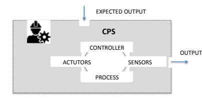
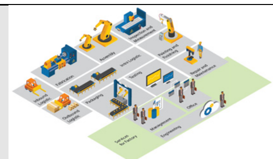
Autonomous Maintenance / Specialist Maintenance	Maintenance – preventive/scheduled maintenance + manage breakdowns and repairs	Down time / waiting – low utilisation Safety	training/competence etc. (and e.g. a TPM approach) great results can be achieved	solutions for low complexity Apply TPM principles Instructions / training

If I remember right, we decided to make this a lower priority at the moment. I have made a few inputs as a start/possible scenario, but this may be clearer when we do an update by M18.

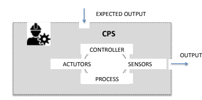
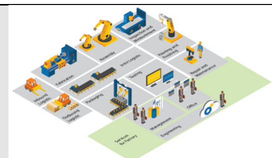
Scenario	GKN-2			
Type	Focus of Scope 1/2/3, i.e re-configure and strat up + operation of the cell			
Scope/1-process view	 In this scenario we can have one or several Cells integrated into the production flows. The assets to the left are different one that will be used in different reconfigurations – not everything at all times in each cell, but can be installed in different cells in the same worksop / product flow	Material handling – in a production cell Machining – (with robots) grinding/polishing Inspection – dimensional measurements, surface finish Storage – in cell buffer / raw material, tools, etc Robots –deburring, tool handling, part handling Human – shop floor operators etc. many different tasks ... Marking – dot pen, vision/camera ... ... maybe some others in the future		Repair & Maint. Intra logistic Inbound logistic Outbound logistic Service for factory Office Mgt Engineering
Scope/2-Production system lifecycle phase	Planning & Engineering Building and adaptation (reconfiguration) Ramp-up Production	Scope/3-Production states	Testing Set-up Processing Failure Maintenance	

	Refurbishment/Dismantling			
Involved human role	**Operators** **Process Engineer** **Product Engineer** **Production Planner** **Supervisor** **Maintenance**			
Human activities	**Short description**	**Potential impact of these activities on performance (KPIs)**	**Barriers and enablers to deploy the full potential of human role (skills, organization, methods, tools, etc.)**	**Preliminary recommendations**
Human identify situation and Intervenes (changes the system State/ expected output, activates other systems, etc.)	**Utilise flexibility is the system, i.e making similar parts but may need different fixture/tooling/process data** **Repair. ..** **Continuous Improvement - implementation** **Problem solving** **...**	**Down time / waiting – low utilisation** **Cycle times** **Quality (=OEE)**	**TBD**	**TBD**
Human analyses and changes the planning	**Decisions about rescheduling to adapt to changes in demand** **Decisions about when to reconfigure the cell** **...**	**Down time / waiting – low utilisation**	**TBD**	**TBD**
Knowledge extraction form human observation	**In case of quality problems ... or breakdowns ...** **Input to improvements** **...**	**Down time / waiting – low utilisation** **Cycle times** **Quality (safety)**	**TBD**	**TBD**
Other	**Possibly ...**			

C. SIEMENS

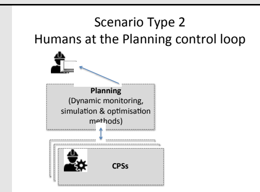
Scenario	**SIEMENS-1**			
Type	**1**	Scenario Type 1 Humans in the CPS control loop 		
Scope/1-process view		**Fabrication** **Assembly** **Inspection & Measuring** **Painting and finishing** **Testing** **Packaging**	**Repair & Maint.** **Intra logistic** **Inbound logistic** **Outbound logistic** **Service for factory**	**Office** **Mgt** **Engineering**
Scope/2-Production system lifecycle phase	**Planning & Engineering** **Building and adaptation (reconfiguration)** **Ramp-up** **Production** **Refurbishment/Dismantling**	**Scope/3-Production states**	**Testing** **Set-up** **Processing** **Failure** **Maintenance**	
Involved human role(s)	**Fabrication operator**			
Human activities	**Short description**	**Potential impact of these activities on performance**	**Barriers and enablers to deploy the full potential of human role (skills, organization, methods, tools, etc.)**	**Preliminary recommendations**
Supervision and set-point adjustment	**not relevant in this scenario**			
Command the system (task execution)	**not relevant in this scenario**			
Data provision	**The operator detects an issue with the machine and creates a ticket (the operator may fill in a**	**This activity influences the**	**The operator may have cognitive or**	**Provide the operator with a situation aware check list of what**

	pre-diagnosis and related information in the system)	part in process and the following. That is may influence through put time, on-time-delivery, OEE	knowledge limitations that prevent good reporting. The operator is not motivated to do a good reporting. The workplace design to make good reporting unpractical (distance, access to data, etc.)	he/she needs to check about the machine and condition-based statements options for supporting the reporting. Provide the operator feedback on the quality of reporting (reputation mechanism? Direct feedback from the maintenance operator? Other mechanisms?) Provide the operator with a mobile device that he/she can interact with while checking the machine, Include a user interface that make it easy to fill in information, by checking multiple options, adding pictures, etc.)
Disturbance	The operator may disregards symptoms of machine malfunctioning	This can lead to failures and increase maintenance efforts.	The operator may not detect or not recognize symptoms. The operator may be motivated (incentive) to prioritize production rather than preserving assets (machine)	Provide alerts and guidance to the operator to create awareness and knowledge support to early detect and report about symptoms. Provide feedback to the operators to made the consider the impact of their decisions to consider or neglect symptoms on the overall performances.
Other				

Scenario	SIEMENS-2			
Type	1	Scenario Type 1 Humans in the CPS control loop 		
Scope/1-process view		Fabrication Assembly Inspection & Measuring Painting and finishing Testing Packaging	Repair & Maint. Intra logistic Inbound logistic Outbound logistic Service for factory	Office Mgt Engineering
Scope/2-Production system lifecycle phase	Planning & Engineering Building and adaptation (reconfiguration) Ramp-up Production Refurbishment/Dismantling	Scope/3-Production states	Testing Set-up Processing Failure Maintenance	
Involved human role(s)	Maintenance operator			
Human activities	Short description	Potential impact of these activities on performance	Barriers and enablers to deploy the full potential of human role (skills, organization, methods, tools, etc.)	Preliminary recommendations
Supervision and set-point adjustment	Maintenance operator can adjust set points to finish production at e.g. lower efficiency for prolonging the life time of a machine	Through put time, OTD, part. OEE	False estimated remaining capabilities might lead to much severe failures/impacts	Provide with best predictions on remaining capabilities
Command the system (task execution)	The maintenance operator is alerted that a ticket has been opened, reads the report and decides the type of intervention.	Impact on costs, through put time	The maintenance operator may ignore the alert because he/she does not access	Provide the maintenance operator with (visual or acoustic ?) alert signals on e.g. mobile devices. Provide the maintenance

			the system for a while. The maintenance operator – in spite of good ticjket quality as for scenario n.1 – may have no knowledge to make the best decision	operator with guidance about the type of interventions associated to the specific condition and related required tools/parts.
	The maintenance operator collects the tools and spare parts that he/she expects to need.	MTTR++	The maintenance operator may not know where and if the needed tools and spare parts are available and which are needed	Provide access to information about availability and location of needed items (i.e. tracking of items, navigation support to reach the warehouse, etc.)
	The maintenance operators goes to the machine			
	The maintenance operator inspects the machine and fix it (minor intervention)	MTTR-	insufficient skills of the maintenance operator to fix the machine.	Training the operator using gamified VR . Support the operator with context –situation aware instructions (AR)
Data provision	The maintenance operator reports about the outcome of inspection/intervention and creates an external maintenance order		The operator may not have a good knowledge about the implications of the required maintenance job.	Provide the operator with a situation aware guidance to allow him/her to characterize the intervention (i.e. necessity to remove the part from the machine, spare parts, tools, time, other requirements.) and fill the information in the system.

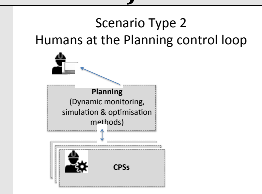
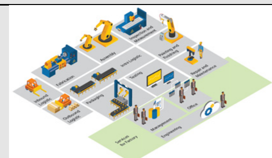
				Provide the operator with a mobile device that he/she can interact with while checking the machine, Include a user interface that make it easy to fill in information, by checking multiple options, adding pictures, etc.)
Disturbance	**The operator fails the diagnosis.**	**MTTR+++**	**Lack of knowledge – experience Low motivation**	**Educate the operator. Provide the operator with guidance (condition-based diagnosis). Provide a suitable and comfortable user interface (smart glasses?) Provide the maintenance operator feedback on the quality of diagnosis**
Other				

Scenario	**SIEMENS-3**			
Type	**2**			
Scope/1-process view		**Fabrication** **Assembly** **Inspection &** **Measuring** **Painting and finishing** **Testing** **Packaging**	**Repair & Maint.** **Intra logistic** **Inbound logistic** **Outbound logistic** **Service for factory**	**Office** **Mgt** **Engineering**
Scope/2-Production system lifecycle phase	**Planning &** **Engineering** **Building and adaptation (reconfiguration)** **Ramp-up** **Production** **Refurbishment/Dismantling**	**Scope/3-Production states**	**Testing** **Set-up** **Processing** **Failure** **Maintenance**	
Involved human role	**Scheduler (so-called)**			
Human activities	**Short description**	**Potential impact of these activities on performance (KPIs)**	**Barriers and enablers to deploy the full potential of human role (skills, organization, methods, tools, etc.)**	**Preliminary recommendations**
Human identify situation	**The Scheduler is alerted about issues with a machine and**	**Throughput time, maintena**	**The Scheduler may have**	**Provide the scheduler with relevant synthetic**

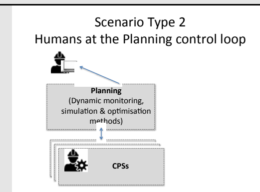
and Interven es (changes the system State/ expected output, activates other systems, etc.)	investigates if it is under repair, not repairable etc. And decide whether to stop continue operation (standard regime) continue operation (downgraded regime)	nce costs, OEE, etc.	incomplet e knowledge about the current status of the machine. The Scheduler may have limited knowledge and bounded rationality about the impact of this decision on performan ces. The Scheduler may have incentive to prioritize production vs. other performan ces	information. Verify the alignment of the objectives and incentives of the scheduler with the overall performances objectives of the factory/company.
Human analyses and changes the planning	The scheduler re-schedules production and maintenance jobs,	" "	The scheduler may not have the cognitive capability and the informatio n necessary to elaborate the best solution. The scheduler may not be aware of all the conflicting objectives. The	Provide support for easily generate, compare and evaluate alternative re-scheduling options. Explicit the impact of alternative decisions of the objectives/perform ances. Visualize trade-off, allow intuitive sensitive analysis to support multi-objective decision making.

			scheduler may be confused about mutli-objective decision setting.	
Knowledge extraction form human observation	**The scheduler or different schedulers address similar situations many times**	**Productivity, effectiveness (w.r.t. the scheduler)**	**The cognitive effort required each time or individual differences may lead to incoherent or inconsistent decision making**	**Provide the scheduler with decision patterns followed in previous situations.**
Other				

D. WHIRLPOOL

Scenario	WHR-1 Fabrication Process (extendible to Value Stream)			
Type	2			
Scope/1-process view		Fabrication Painting and finishing Assembly Inspection & Measuring Testing Packaging	Repair & Maint. Intra logistic Inbound logistic Outbound logistic	Service for factory Office Mgt Engineering
Scope/2-Production system lifecycle phase	Planning & Engineering Building and adaptation (reconfiguration) Ramp-up Production Refurbishment/Dismantling	Scope/3-Production states	Testing Set-up Processing Failure Maintenance	
Involved human role	Industrial Engineers			
Human activities	Short description	Potential impact of these activities on performance (KPIs)	Barriers and enablers to deploy the full potential of human role (skills, organization, methods, tools, etc.)	Preliminary recommendations
Human identify situation and Intervenes (changes the system State/ expected output, activates other systems, etc.)	Management identify potentiality to improve Fabrication process based on KPI and request a team to act in order to improve the situation.	All potential KPI involved		
Human analyses	Team is requested to solve a problem related	All potential	Shortage of skills to use a	Model able to grow

and changes the planning	**to cost, capacity, quality etc. coming from management. Team study the model and analyses data to find potential correlation with production parameters and requested final state (described by a set of KPI). Team apply simulation tool to verify how potential reconfiguration influence output KPI. Team apply the changes to the real system.**	**KPI involved**	**model and a simulation method. Model not able to capture all the complexity of the real situation.**	**along with the people skills. Data should be available through mobile device in a contextualiz ed way (e.g. based on human role and geographical position)**
Knowledge extraction form human observation	**Team measure the real application of the reconfiguration (through initial KPI) and re-adjust the model with newly extracted knowledge.**		**Shortage of skills to use a model and a simulation method. Model not able to capture all the complexity of the real situation.**	
Other				

Scenario	**WHR-2 Leak test**			
Type	**2**			
Scope/1-process view		**Fabrication** **Assembly** **Inspection & Measuring** **Painting and finishing** **Testing** **Packaging**	**Repair & Maint.** **Intra logistic** **Inbound logistic** **Outbound logistic**	**Service for factory** **Office Mgt** **Engineering**
Scope/2-Production system lifecycle phase	**Planning & Engineering** **Building and adaptation (reconfiguration)** **Ramp-up** **Production** **Refurbishment/Dismantling**	**Scope/3-Production states**	**Testing** **Set-up** **Processing** **Failure** **Maintenance**	
Involved human role	**None**			
Human activities	**Short description**	**Potential impact of these activities on performance (KPIs)**	**Barriers and enablers to deploy the full potential of human role (skills, organization, methods, tools, etc.)**	**Preliminary recommendations**
Human identify situation and Intervenes (changes the				

system State/ expected output, activates other systems, etc.)				
Human analyses and changes the planning				
Knowledge extraction form human observation				
Other				

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